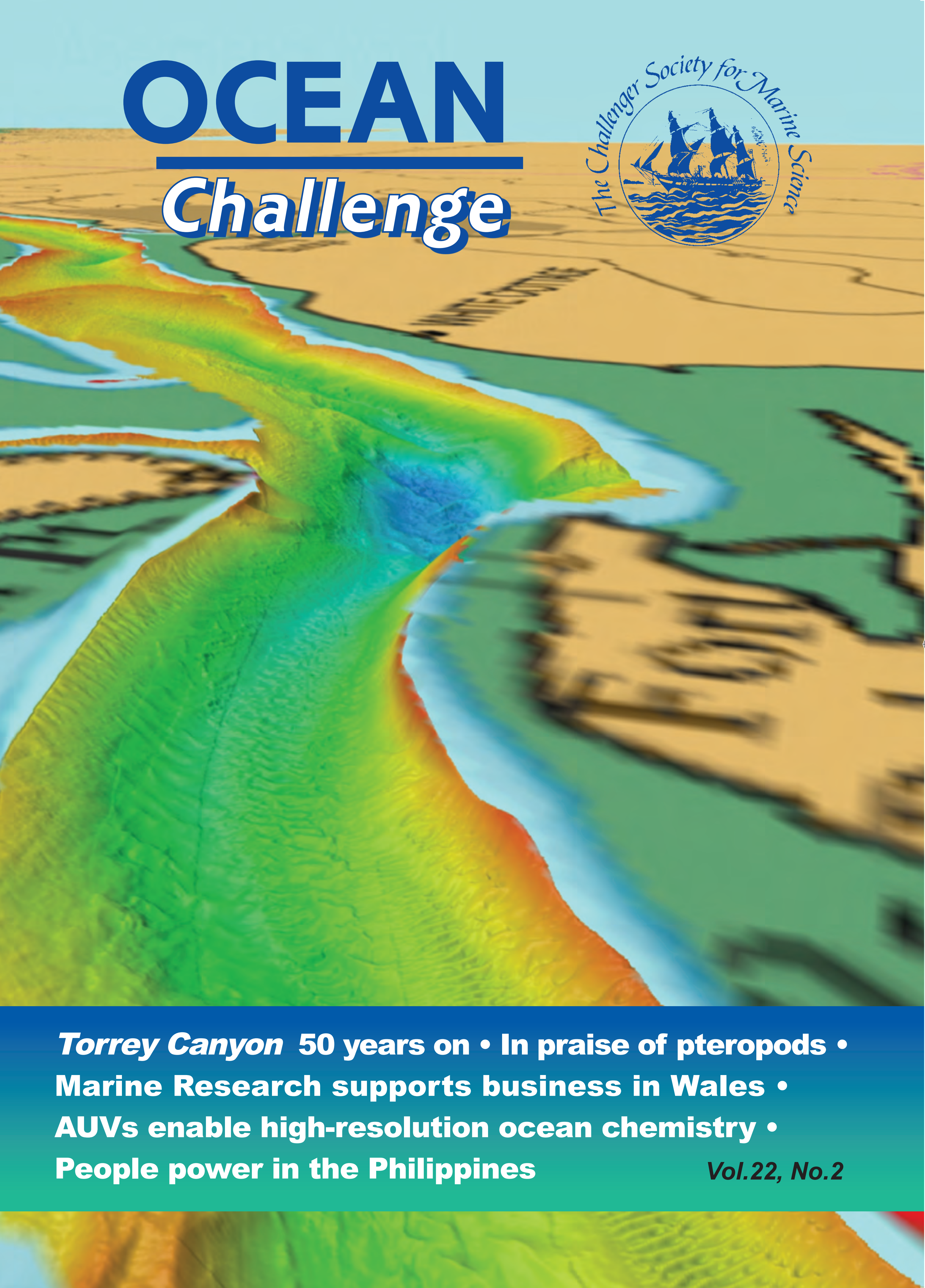

OCEAN Challenge

The Challenger Society for Marine Science

Torrey Canyon 50 years on • In praise of pteropods • Marine Research supports business in Wales • AUVs enable high-resolution ocean chemistry • People power in the Philippines

Vol.22, No.2

OCEAN Challenge

Volume 22, No.2, 2016
(published 2018)

The views expressed in *Ocean Challenge* are those of the authors and do not necessarily reflect those of the Challenger Society or the Editor.

SCOPE AND AIMS

Ocean Challenge aims to keep its readers up to date with what is happening in oceanography in the UK and the rest of Europe. By covering the whole range of marine-related sciences in an accessible style it should be valuable both to specialist oceanographers who wish to broaden their knowledge of marine sciences, and to informed lay persons who are concerned about the oceanic environment.

Ocean Challenge can be downloaded from the Challenger Society website free of charge, but members can opt to receive printed copies. For more information about the Society, or for queries concerning individual or library subscriptions to *Ocean Challenge*, please see the Challenger Society website (**www.challenger-society.org.uk**)

INDUSTRIAL CORPORATE MEMBERSHIP

For information about corporate membership, please contact Terry Sloane Terry@planet-ocean.co.uk

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ISSN 0959-0161 Printed by Halstan Printing Group

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OCEAN Challenge

The Magazine of the
Challenger Society for Marine Science

SOME INFORMATION ABOUT THE CHALLENGER SOCIETY

The Society's objectives are:

To advance the study of marine science through research and education

To encourage two-way collaboration between the marine science research base and industry/ commerce

To disseminate knowledge of marine science with a view to encouraging a wider interest in the study of the seas and an awareness of the need for their proper management

To contribute to public debate and government policy on the development of marine science

The Society aims to achieve these objectives through a range of activities:

Holding regular scientific meetings covering all aspects of marine science

Setting up specialist groups in different disciplines to provide a forum for discussion

Publishing news of the activities of the Society and of the world of marine science

Membership provides the following benefits:

An opportunity to attend, at reduced rates, the biennial UK Marine Science Conference and a range of other scientific meetings supported by the Society. Funding support may be available

Receipt of our electronic newsletter *Challenger Wave* which carries topical marine science news, and information about jobs, conferences, meetings, courses and seminars

The Challenger Society website is
www.challenger-society.org.uk

MEMBERSHIP SUBSCRIPTIONS

The annual subscription is £40 (£20.00 for students in the UK only). If you would like to join the Society or obtain further information, see the website (given above).

COUNCIL FOR THE CHALLENGER SOCIETY

For information about Council members see the Challenger website

ADVICE TO AUTHORS

Articles for *Ocean Challenge* can be on any aspect of oceanography. They should be written in an accessible style with a minimum of jargon and avoiding the use of references. If at all possible, they should be well illustrated.

For further information (including our 'Information for Authors') please contact the Editor:

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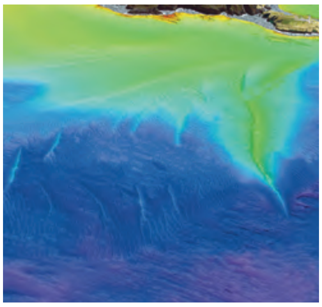


Most of the maps and diagrams were drawn by The ArtWorks.

The cover and heading graphics were designed by Ann Aldred.

The cover image was generated from multibeam sonar data collected and processed by Jim Bennell, School of Ocean Sciences, Bangor University, through research undertaken as part of the SEACAMS Project.

CONTENTS

Message from the Editor 2

Challenger Society awards and prizes 2

Some dos and don'ts for posters and presentations 4

The new Challenger Society History Special Interest Group 5

Reflections on marine data science
Matt Donnelly, George Graham and Clint Blight 6

***Torrey Canyon* 50 years on:** Eve Southward recounts the MBA's response to an environmental disaster 8

An interview with marine biologist Eve Southward 10

Recollections of Graham Shimmield: Nick Owens pays tribute and shares some reminiscences 13

Decom or not to decom? It's not just a question of cash *Kelvin Boot* 14

Hanging out with pteropods *Corinne Pebody* 17

Coral Cay Conservation and citizen science: how volunteers are contributing to marine conservation in the Philippines
Tom Dallison and Tessa Dawson 20

A new era for ocean observation: AUVs coupled with chemical sensors will enhance our understanding of the marine environment *Peter J. Statham* 26

SEACAMS: Collaboration between marine research and business in Wales
Colin Jago and Michael Roberts 30

A 'cranky little vessel' – the story of HM steam vessel *Lightning*: Part 3 Events, dear boy, events!
Tony Rice 33

Message from the Editor

Many apologies for the late arrival of Vol. 22(2) of *Ocean Challenge.* The issue was near publication at the end of 2017, when were hit by a computer disaster. All files were backed up but getting back to where we were has been a real challenge. I would like to thank authors for their patience and understanding.

In the work done to set up the new Search system on the website, a group of us looked at all past issues of *Ocean Challenge*, and in the process came across articles on projects and research that it would be interesting to follow up on. As a result, the feature article in this issue is about the valuable work of Coral Cay Conservation, which we first reported on in 1991. Along with the usual mix of shorter articles, we have an appreciation of the late Professor Graham Shimmield, who is greatly missed by many of us in the oceanographic community. Angela Colling

Challenger Society awards and prizes

As usual, a number of awards and prizes will be made at the Challenger Conference, the most prestigious being the Challenger Medal which is awarded to a distinguished UK marine scientist. Challenger fellowships – including the new one described below – will be awarded to early-career marine scientists for achievement or promise. Also new is an award intended to raise the status of oceanographic education and to encourage oceanographic research among undergraduates in ocean sciences, geography, environmental sciences and related disciplines. At the conference itself, there are prizes to be won by students/early-career scientists for the best poster and the best talk (for tips, see p.4).
For full details of all these awards/prizes, see the Challenger website.

Challenger Society Fellowship in Nutrients and Nutrient Cycling in the Ocean

This £2000 Fellowship, made possible by a generous gift from Malcolm Woodward, will be presented biennially to an early career stage marine scientist carrying out research in the field of nutrients and nutrient cycling in the oceans, in recognition of their achievements and promise. The bursary will provide support for the Fellow to attend conferences/workshops, travel for fieldwork, and carry out activities aligned to the objectives of the Society for a period of up to two years following award.

Nominations/eligibility

- Nominees should be outstanding early-career researchers, with potential as a future leader in marine science.
- Nominees will have a Ph.D in a relevant subject and will not normally have been employed for more than 10 years (full-time equivalent) post Ph.D award.
- The nomination should be submitted by a single proposer with support provided in writing by one or (preferably) two other members of the Society and/or other marine scientists of appropriate standing in the community. The letters of support should be included with the submission of the proposal along with a short CV of the nominee.
- Nominations should be submitted to the President of the Society Rachel.Mills@soton.ac.uk before 1 May.
- Nominees should be members of the Society.

Marine Science Undergraduate Student Award

Letters of invitation are being sent to relevant university departments inviting them to submit suitable dissertations from final-year undergraduate students.

Students can only be entered by the Convenor of the final-year dissertation module from universities located within the UK. Only one submission will be accepted from each department and it should be of outstanding quality. Prize(s) will be awarded after consideration by a panel drawn from the Challenger Society's Council.

Entries will be judged on the following criteria: overall excellence in the project; originality, or uniqueness of the project; standard of presentation; relevance to oceanography.

The winning student will receive a cheque for £500 and one year's complimentary membership of the Society. In exceptional circumstances the Award may be shared.

President's Photographic Prize

For the Newcastle Conference we are looking for beautiful and entertaining photographs on the theme of 'Sustainable Oceans'. There will be a fabulous prize for the best picture, as judged by the outgoing President and the President Elect.

So please email your entries to Rachel Mills (Rachel.Mills@soton.ac.uk) before the start of the Conference.

NB: You should bear in mind that images need to be at sufficiently high resolution to look good when printed, not just on screen. Photos may be used in future publications of the Society, with the owner's permission.

Dr Erik van Sebille

Professor David Holland

Professor Bess Ward

Dr Stephanie Henson

Some dos and don'ts for posters and presentations

If you have your eye on the prizes to be won for posters and talks at the 2018 Challenger Society Conference, here are some tips. The poster prize honours Cath Allen, a researcher in fluid dynamics at the University of Lancaster, who died in 1991. The Challenger Society introduced the prize to combat the idea that contributing to a conference poster session is a second best alternative to delivering a paper, even though a poster needs to be at least as well thought-out as a talk. The prize for the best talk honours Norman Heaps, a shelf-sea modeller who died in 1986. He was a particularly clear speaker, with an enthusiastic, lively and entertaining way of delivering a talk.

The Cath Allen Poster Prize

- A poster is a chance to use your skill in presentation of data, in layout, and in distilling the essence of your message. **It is not an abbreviated paper**.
- **A poster needs to be attractive**, with an interesting title that is visible from a distance. If a poster doesn't draw attention to itself, it could be overlooked, and all the work put into it could be wasted.
- **A poster needs to be easily readable**, and not just by someone standing really close to it. For the main text, take care to choose a clear type-face at sensible point size. Avoid long complex sentences.
- **Avoid large slabs of text** and overlong line-lengths; the optimal line-length for readability is considered to be 50–65 characters per line, including spaces. For consistent spacing between words, use unjustified text.
- **Ensure your diagrams are large enough** to be seen clearly, and that the line weights of graphs etc. aren't too spindly.
- **Ensure that you have explained your symbols and acronyms,** and have put scales on figures if necessary.
- **Try not to have more than about five figures** (diagrams and photos). Remember that a well-chosen picture can be worth a thousand words.
- **Diagrams need to be close to the text** that relates to them, **or very easily found**.
- **Make use of colour** to enliven the poster and help direct the reader where to look.
- **Don't be tempted into over-complicating the appearance of the poster**, and obscuring your message.
- **Try to convey why your research is so exciting**.
- **Be there by your poster to answer questions**.

The Norman Heaps Prize

- **Time your talk beforehand.** There is nothing more upsetting than having to leave the podium without getting to your conclusion.
- **Beware of overload**. It's not advisable to have more than about half-a-dozen pieces of 'hard' information (diagrams, maps, tables) per 15 mins of presentation. **That's still only 2.5. minutes per picture.** (This doesn't preclude any scene-setting photos.)
- Don't forget that **your time slot includes** 2–3 minutes for **questions.**
- Everyone uses their Powerpoint slides as memory prompts, but **try not to find youself just reading from them or you will lose spontaneity**.
- In particular, reading through introductory slides that show the title, the aims, methods, results and even conclusions, takes up valuable time and isn't necessary, as the Chair will have already introduced you, and the audience has the book of abstracts. **If you are determined to have an introductory slide, make it brief and interesting**.
- Your results may be fascinating, but that's irrelevant if they can't be read from further back than the first two rows. **Graphs and diagrams are easier for an audience to take in than tables**. If you do use tables, highlight the numbers you are talking about.
- **Make use of colour** to enliven your graphics and help convey your storyline.
- **Use variety – switch between text, diagrams and photos**. If you use visuals from a number of sources, ensure that they use the same conventions for symbols etc.
- **Remember who your audience are**. Challenger conferences are attended by marine scientists from all disciplines, each with their own vocabulary, so try to explain any specialist terms so that everyone can follow your talk.
- **Try to convey why your research is so exciting.**

The new Challenger Society History Special Interest Group

Whatever your area of marine science, there is one Special Interest Group that caters for you – the Challenger Society History SIG. Re-formed a year ago the group's overall aim is to raise interest in, and to document, the development of all areas of UK marine science.

What activities is the SIG promoting?

Photographs Do you or your lab have photographs of historically important activities? Have they been scanned? Are they available online? It is important to find missing metadata – e.g. who the people shown are, or what equipment is being used. We are ancouraging the collection of metadata, because without it the value of photographs is greatly reduced.

Equipment Does your lab have pieces of equipment, big or small, that are no longer used yet may be of historical importance? Please let us know before they go in the skip to be recycled. They may be of interest to the Science Museum who hold such things, from the big and relatively modern (the *GLORIA* side-scan sonar vehicle) to the small and old (hydrometers and thermometers used in the era of HMS *Challenger*).

People We are compiling a list of the published, and as yet unpublished, biographical information about UK marine scientists as a resource for the community. When it is available please let us know about information that we may have missed.

Talks and meetings We will encourage meeting convenors to inject an historical element into their sessions, and will hold dedicated meetings on historical aspects of our science.

The History SIG already has over 40 members and welcomes more. It is free. If you are interested, please contact John Gould wjg@noc.soton.ac.uk or Philp Woodworth plw@noc.ac.uk, and have a look at the History SIG link on the Challenger Society website.

For information about the Sea Level Challenger SIG, see p.19

Reflections on Marine Data Science

Matt Donnelly, George Graham and Clint Blight

The inaugural meeting of the Challenger Special Interest Group dedicated to data management and informatics across the spectrum of marine sciences was held after the 2016 Challenger Conference. As the 2018 Conference approaches, we reflect on this first meeting and what the future may hold.

The meeting consisted of three oral sessions, posters over lunch, and a round-table discussion regarding the future of the new SIG.

Presentations

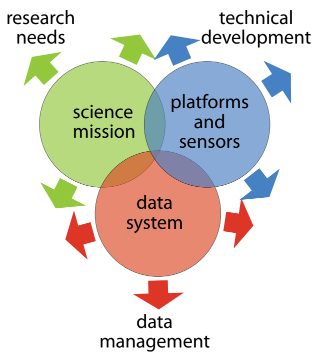
The oral sessions were started off by Katie Gowers from the British Oceanographic Data Centre (BODC) on the value of data management skills, and the range of these skills required to reliably and confidently 'torture the data'. This was followed by the Coordinator of the Marine Environmental Data Information Network (MEDIN), Clare Posthlethwaite, on MEDIN'S role in building and facilitating capabilities across a range of marine science disciplines – from oceanography through to archaeology. Jo Beja from BODC detailed the work undertaken by the Southern Ocean Observing System (SOOS) to develop a research platform to support field programmes in that most challenging of regions. The first session concluded with a whistle-stop tour of the Surface Ocean Carbon Atlas (SOCAt) Live Access Server (LAS) presented by Matthew Humphreys from the University of Southampton.

The second session began with the deepest of all marine sciences by looking at the data management of sediment core samples, presented by Suzanne MacLachlan from the British Ocean Sediment Core Facility (BOSCORF). Andy Matthews from NOC (Liverpool) then brought us back to the surface by explaining the challenge for the Permanent Service for Mean Sea Level (PSMSL) in managing metadata for the 200-year-long global sea-level dataset – lessons that younger sustained observation programmes could take heed of by planning for the growing demands for complex metadata over time. Mike Osborne from OceanWISE provided an overview of an application of Sensor Web Enablement (SWE) as one of the options for managing increasingly diverse data and metadata in the connected future Internet of Things. Rob Thomas from BODC (now Marine Institute, Ireland) gave a clear account of the well established importance of using controlled vocabularies to standardise and manage metadata. The second session was rounded off by Justin Buck (BODC) with a look at recent international developments for the unambiguous citation of growing datasets through the use of time-citable Digital Object Identifiers (doi's), such as those used in the international *Argo* programme.

Our third session looked at some institutional initiatives including the engaging 'Fun with Flags' from Bee Berx, who explained the work being done at Marine Scotland to review their quality control procedures. Co-convenor Clint Blight shared the background on the work he has undertaken to develop a system to enable a small marine lab to manage its data and metadata right from the beginning of a project by using the Digital/Data Assembly/Archive System/Storage (DAS) system at the Sea Mammal Research Unit (SMRU). Our other co-convenor, George Graham, from the Sir Alister Hardy Foundational for Ocean Science finished off the oral presentations with a look at data management and computational skills training. He posed the hypothesis that comprehensive training in data science skills could help accelerate science and develop communities of best practice to support researchers in data-intensive work.

The poster session alongside lunch then provided an opportunity to take a look at a number of other topics, including:

- how near-real-time data systems can enable integrated data systems, from Matt Donnelly (BODC);
- a focus on how MEDIN works to improve stewardship of marine data, from Sean Gaffney (MEDIN);



Venn diagram depicting the challenge of aligning research needs, technological development and data management, from Matt Donnelly's poster on enabling integrated data systems

- the role of DASSH as the archive for marine species and habitats data, from Matt Arnold (Marine Biological Association);
- data management in a government fisheries laboratory from Adam Mellor (Agri-Food and Biosciences Institute of Northern Ireland, AFBINI);
- the use of linked data to aid the development of a metadata portal supporting the Marine Strategy Framework Directive (MSFD), from Chris Wood (BODC); and
- development of an ocean data tool, ODaT, based on Hydrobase, from Sam Jones (SAMS).

Round-table discussion

Together, the oral and poster presentations covered a wide range of data management and informatics – perhaps wider than we initially anticipated – and shed light on areas of marine science that were often on the periphery of the interests of many of those in attendance. The experience of participants and the presentation content provided a great basis for our round-table discussion. During lunch, members of the group submitted areas for consideration which were grouped into themes to be discussed during our afternoon session.

The way forward for the community

Our first point for consideration was simple: Was this the right forum for discussing data and informatics, and did we have the right name? It was agreed that there was value in having a dedicated Challenger group for this aspect of marine science, and it was identified as a unique forum for open discussion and sharing on common challenges. More of a challenge though was the name: 'Marine Science Data Management' seemed too narrow to encompass the range of participants, experiences and expertise present, so many other ideas were thrown into the hat. We decided we would need to think further to ensure we proceed under a name suited to a new collaborative forum at a 'grass-roots' level for a diverse group of professionals. Following further review, the new name of 'Marine Data Science' Special Interest Group has been adopted.

It was well observed that, despite the uniqueness of our new forum, there are data centres, MEDIN, Challenger itself, MASTS and other bodies with an interest in data management or in stimulating community-driven initiatives. The new SIG neither could nor should attempt to duplicate the role or functions of any existing body, but it was agreed that – alongside normal knowledge sharing – there was clear scope for the SIG and its members to serve as a key community-level expert group. Whilst this idea needs to be explored further, the membership of the group could provide the nucleus for working groups collaborating with other bodies, and act as a critical friend to organisations where appropriate.

Finally, there was the issue of wider engagement with the marine science community, ensuring the involvement of researchers as well as data managers and informatics professionals. It was widely felt that the involvement of a wide base from within the community was important for sharing a rich wealth of experience across institutions, disciplines, networks and industry. The group agreed that, ideally, future meetings should avoid clashing with those of other SIGS, so that as many interested people as possible could attend.

Accreditation

The group discussed the role that accreditation currently plays in marine informatics and data management, and how this might be developed in the future. It was unanimously agreed that the SIG was not the appropriate body to facilitate accreditation, but that we might be able to identify community needs and play a key role in developing the landscape around raising standards of data management. To this end, it was noted that it would be worth developing a better understanding of what other branches of environmental science are either currently doing, or seeking to develop, for accreditation purposes.

At present, only marine data centres receive accreditation from MEDIN under a Bronze/Silver/Gold system, but accreditation does not currently extend to individual research institutions or university departments. MEDIN was considered the most appropriate organisation to facilitate broadening such institutional accreditation, but it was agreed that work would be needed on this front to scope out what a 'kite mark' scheme might comprise and whether there was demand for such a scheme.

As far as professional accreditation for individuals is concerned, the group was aware of accreditation offered by the Chartered Institute of Library and Information Professionals and the Chartered Institute of IT 'Data Management Professional' qualifications, but there appears to be no more widely applicable/generic data science accreditation. Discussion on this front covered the potential for both accreditation of marine data science professionals and the wider professional recognition of research and commercial scientists in this field. An organisation, perhaps IMarEST, was considered the preferred route for individual accreditation, but it was agreed that a deeper understanding of the currently available options was needed.

It was generally agreed that this was an area were the SIG could act as the pivotal community group representing all those involved in marine data science and that this was a potential area of focus for a future SIG meeting.

Data science training

This section of the discussion was well introduced by George Graham's presentation on better computational skills training as a route to accelerating science. There was a broad consensus amongst the group that there was insufficient training in data management and informatics for all levels of expertise from undergraduate up to PI, with few training courses on offer. Furthermore, although the group exchanged many examples of what might be important in a marine data science training course, it became clear that there was a need to develop the efforts of various individuals and institutions into a more comprehensive curriculum package.

Various organisations represented at the meeting had delivered data management and informatics seminars to institutions, run short undergraduate and postgraduate training courses, or provided bespoke training to particular groups using certain tools. It was felt that, collectively, there was enough experience of both data science and delivering training for the group to develop a range of training materials amongst themselves. These could range from a domain agnostic 'data management 101' course through to more advanced concepts and specialist skills suitable for marine scientists of various backgrounds and career levels.

A discussion on options to develop such training included:

- creating short presentations as an introduction to more in-depth resources;
- integration of data science training with postgraduate programmes and summer schools;
- linking up with early-career bodies such as those of Challenger and the UK Polar Network to arrange and deliver courses;
- consider contributions to the IODE Ocean Teacher Programme;
- compiling a glossary of data management terms which could be hosted on the Challenger SIG webpage.

Discussion mostly focussed on the need to train the next generation of researchers, potentially through Doctoral Training Partnerships (DTPs), but with a need to develop a better knowledge of user requirements to inform an optimal training package. Alongside this was a recognition of a need to support established scientists in light of increasing data openness, stringent requirements associated with data sharing from RCUK grant funders, and submission of data to national data centres for long-term archiving.

The outcome of the discussion centred on the question: Could the SIG facilitate the development of a course for data intensive marine science equivalent to the sea survival course? The key limiting factor, though, was the availability of resources.

Technical questions

The first technical issue to be discussed related to the automated upload facility provided by the Surface Ocean Carbon Atlas (SOCAt) Live Access Server for surface carbon data, which is identified as being efficient and intuitive to use. It was noted that this facility is a bespoke system for a specific community. Equally, whilst no universal data upload system exists, the same principles could be applied to a wide variety of data types.

Quality control flagging schemes were also discussed as there are so many, from so many different sources, for a range of different applications, which have in some cases varied over time. This was identified as having created some uncertainty for labs as to what they should ideally be using, or whether there was any ideal at all. This applied not only to NERC-funded research data destined for a NERC data centre like BODC, but also to industry and higher education institutions who have their own archival needs and obligations. It was agreed that for oceanographic data it would be useful for BODC to review its own knowledge and provide advice on best practice.

The future

The new Marine Data Science Special Interest Group has many avenues to pursue, and we look forward to making progress on some of the topics discussed at our inaugural meeting and reporting on them to you. If you are interested in the SIG please contact us at: data.science@challenger-society.org

Matt Donnelly is the Lead Data Scientist for the *Argo* programme at BODC.
George Graham is the Marine Instrumention Scientist and Data Team Manager at SAHFOS.
Clint Blight is the Scientific Software Engineer and Geoinformatician at SMRU.

Torrey Canyon *50 years on*

Eve Southward recounts the MBA's response to an environmental disaster

The tanker *Torrey Canyon* struck the Seven Stones Reef off Land's End, Cornwall, on 18 March 1967 while *en route* to Milford Haven, and the cargo of about 119 000 tonnes of Kuwait crude oil started to escape from the damaged ship immediately (Figure 1). The government and armed forces took charge of clean-up operations after attempts to tow the wreck off the reef failed, and oil dispersants (detergents) were sprayed on the oil slick from Royal Navy ships and others. Ten days after running aground, the wreck was bombed by the RAF and some of the cargo was burned, but the fires went out and leakage continued until, towards the end of April, the empty wreck sank. The floating slick was moved by wind and tide (Figure 2) and the oil fouled the shores of west Cornwall between 24 and 29 March, and the Channel Island of Guernsey on 7 April. North Brittany was reached on 10–12 April.

Thousands of sea birds were the first victims of the oil but this spill became notable for the enormous amount of oil-spill dispersants used in operations at sea and on Cornish shores. They were first used at sea to try to disperse the floating oil after the spill, and were also sprayed (usually diluted with water) on the oily rocky shores and sandy beaches. The toxicity of such dispersants was not fully understood at the time of the disaster and they had a devastating effect on the fauna and flora.

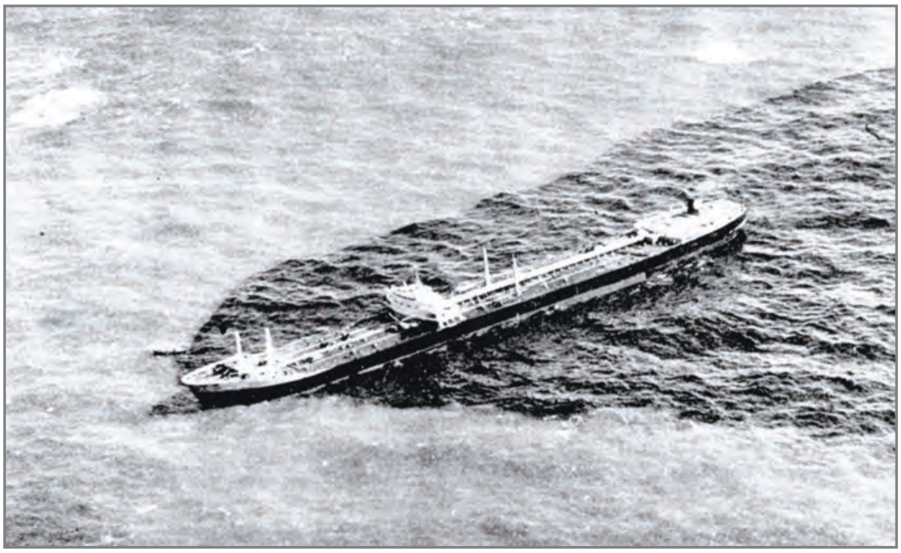
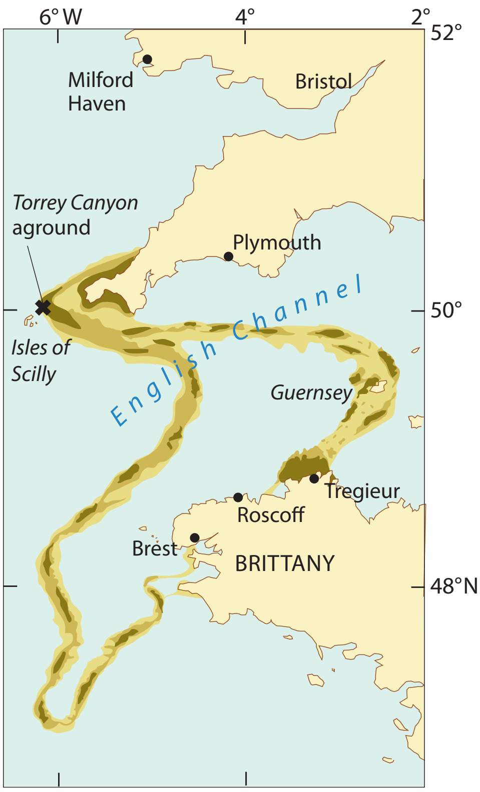


Figure 1 *The Torrey Canyon on the Seven Stones Reef, 18 March 1967 (© Mariners' Museum)*

Many official and voluntary bodies became involved in the subsequent clean-up and its consequences. As soon as the large-scale use of detergents became known and the pollution of large stretches of the Cornish coastline was seen to be inevitable, it was decided to divert the entire resources of the laboratory of the Marine Biological Association at Plymouth to study the effects of oil and detergent pollution on intertidal and offshore marine life in the area. Work started on 26 March and continued until mid-June – although some people at the laboratory continued for much longer. A report was completed by mid-September and published as a book in spring 1968.

On 28 March the MBA's research vessel *Sarsia* (Figure 3) set off from Plymouth to



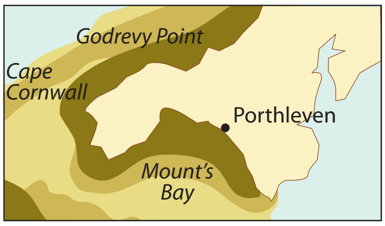


Figure 2 ***Left*** *Approximate track of the oil from the* Torrey Canyon *and the places where it came ashore.* ***Top right*** *Locations mentioned in the article. (From Smith (1968), see Further Reading)* ***Bottom right*** *The oiled shore at Porthleven in 1967, after 'cleaning'. (Photo: Alan Southward)*

Figure 3 *The* Sarsia*, the MBA's research vesssel at the time of the spill.*

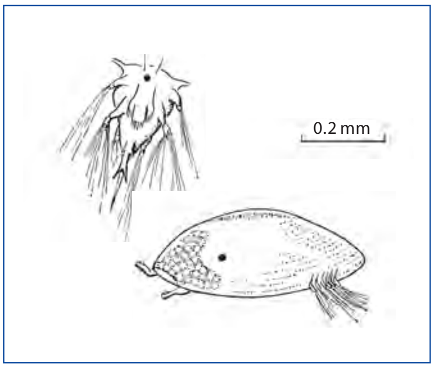
take samples of water, plankton and fish in Mount's Bay and the Seven Stones area. Gerald Boalch, the Chief Scientist on the cruise remembers:

When we steamed west on Sarsia *the first thing we noticed before we saw the oil was the dreadful sickening smell. When we did reach the oil it was like a thick rust-red layer on the surface. Local boats were out spraying the oil with detergent and the oil was obviously being broken up and dispersing. We realised that the detergent was breaking up the oil but was probably making it more accessible to the marine life. At that time we had no information on the toxicity of the detergent. We sampled the plankton in the area where the oil was being treated and under the microscope could see that some species of the plankton were being killed.*

Local people were also involved in attempts to deal with the spill, but frequently felt that their knowledge and suggestions were ignored by the 'experts'. When interviewed in 2011, members of local communities commented on the nauseating smell and the brown colour of the incoming oil on the sea. They feared for their livelihoods and the likely effect on the 1967 tourist season.

My own involvement began with exploratory experiments – with Alan Southward and Eric Corner – on the toxicity of the detergents on the larvae of a common intertidal barnacle, *Elminius modestus* (Figure 4). We tested four brands of detergent employed at the time, in comparison with the laboratory detergent Teepol and samples of Kuwait crude oil. All four brands were more toxic than Teepol or Kuwait crude. The relative toxicity of the various brands depended on the types and quantities of organic solvent components. Other researchers found similar effects on other types of planktonic larvae and phytoplankton species in culture.

Figure 4 *Drawings of barnacle larvae copied from Smith 1968 (see Further Reading)*



Alan and I then turned our attention to the effects of oil and detergent on the ecology of the Cornish rocky shores, for which we had some 10 years' earlier data. MBA workers visited 65 sites between mid-March and mid-May. 18 main sites were obviously heavily polluted and most of these were 'cleaned'. It was difficult to find a shore that had been oiled and not cleaned, but the shore at Godrevy Point (close to a seal colony) was patchily oiled and not directly treated with detergent because of objection by the National Trust. This became our control site in future years.

On heavily detergent-treated shores tufts of bleached seaweeds and empty shells could be seen. The rocks looked clean, even white. In the absence of most grazing animals, ephemeral green algae could settle and grow, turning the shore green within the first year, and the green algae were succeeded by a heavy settlement of brown algae (Figure 5). At Godrevy Point, most of the limpets survived under a light coating of oil, there was no greening and the shore returned to normal within two to three years. The recovery of dispersant-treated shores to 'normal' took 5 to 10 years. Up to 50 years' follow-up observations, including photographs, are now available for five of the major *Torrey Canyon* sites, showing the extent of the recovery phases and later natural fluctuations in algal cover and animal populations.

Figure 5 *Intertidal rock platform at Cape Cornwall before and after the Torrey Canyon oil spill and clean up.*
(Photos: Alan and Eve Southward)

Further reading

Smith J.E. ed. (1968) Chapter 4 in *'Torrey Canyon' Pollution and Marine Life,* Marine Biological Association of the UK and Cambridge University Press, 196pp.

Green A. and T. Cooper (2015) Community and exclusion: the *Torrey Canyon* disaster of 1967. *Journal of Social History* **48** (4), 892–909.

Corner, E.D.S, A.J. Southward and E.C. Southward (1968) Toxicity of oil-spill removers ('detergents') to marine life: an assessment using the larvae of the intertidal barnacle *Elminius modestus*. *Journal of the Marine Biological Association* **48**, 29–47.

Southward, A.J. and Eve C. Southward (1978) Recolonization of rocky shores in Cornwall after use of toxic dispersants to clean up the *Torrey Canyon* spill. Symposium on Recovery Potential of Oiled Marine Environments. *Journal of the Fisheries Research Board of Canada* **35**, 5, 682–706.

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This article was originally published in The Marine Biologist *magazine.*
See http://www.mba.ac.uk/50th-anniversary-environmental-disaster and https://www.mba.ac.uk/sites/default/files/katcla/50_year_anniversary_of_Torrey_Canyon_more_info.pdf

An interview with marine biologist Eve Southward

Many marine biologists will know Eve Southward as one half of the publishing partnership 'Southward and Southward', the other half being her late husband, the eminent researcher, Alan Southward. But Eve is a fine scientist in her own right, and is an expert on polychaetes, Pogonophora and hydrothermal vent fauna, amongst other groups. With her skill for identifying organisms, Eve has been in great demand on cruises, and has described many new species during her career – the pogonophoran *Diplobrachia southwardae* was named after her. Here Eve describes what it was like to be a student of marine biology in Liverpool and Plymouth in the 1950s and '60s, and explains how the accumulating interests of her fascinating career have been the result of a series of chances. *Ed*

Did you always want to be a biologist?

When I was young, we didn't really talk about careers. I was very keen on doing analytical chemistry as one of my subjects for what would now be called A Level, but I was told that I wasn't good enough at maths, so I dropped physics and changed over to biological subjects. I liked identifying plants – I grew up with Kew Gardens and the Natural History Museum on my doorstep. During the war, I spent three or four years in a village north of London, where I saw farm animals, garden plants, great crested newts, birds – It was all just 'natural history'. I didn't know what ecology and fieldwork were, but I was actually doing them – that was the way my mind worked!

Wondering what to do at university, I ended up thinking about going to Reading to do Agriculture and Horticulture, then a neighbour, who was a professor at Liverpool, suggested I go there and read Marine Biology under the famous Professor Orton. I'd hardly ever heard of Marine Biology, so I looked it up in Encyclopedia Brittanica! I thought 'Marine Biology sounds interesting, let's find out more.' I read C.M. Yonge's The Sea Shore *and enjoyed a holiday by the seaside, so in 1949 I went off to Liverpool and did Honours Zoology with Marine Biology as my separate subject.*

How was Marine Zoology taught in Liverpool in that post-war period?

By the time I got to Liverpool, Professor Orton had retired early due to illness, and I was the only Marine Biology student in my year. But at that time, the Port Erin Marine Biological Station on the Isle of Man was very active, and all the botanists and zoologists were expected to go on a two-week Easter course at Port Erin for their first two years.

As an Honours student I did practicals in the Zoology Department, and I was instructed by the freshwater biologist Noel Hynes. The chief technician went down to the fishmarket every week, and bought a few interesting fish for me to identify, dissect and study. Then in the summer term, I went off to Port Erin and did a project with John Colman who used to work on the fauna of Laminaria *holdfasts. He put me onto the fauna living on* Corallina *– a tiny seaweed – living on the seashore. I also got training from the fish biologists and ecologists.*

When it came to the end of the year, there was the possibility of a Herdman Postgraduate Studentship in Marine Biology. I was the only eligible student, so I got it without even applying! For my topic I was given polychaetes of the Isle of Man, as it was next on the list, because the previous student, who had been allocated polychaetes, wanted to work on seals. Norman (N.S.) Jones was my supervisor.

So I joined the other Ph.D students, and we went around on foot and bicycle, studying the many good habitats available at Port Erin. It's a great shame that Port Erin was closed in 2006 – there wasn't enough money or enthusiasm from the Isle of Man government or Liverpool University to keep it open.

How hard was it to to find a job?

I didn't really have to – after two years' fieldwork for my Ph.D, I married a fellow student, Alan Southward. He already had his Ph.D, and he got a fellowship at the MBA so I came down here to Plymouth too. We shared a room, I had a microscope, and I became part of the furniture. Alan and I were a good team. He helped me a lot, and I helped him with his fieldwork, and we would do barnacle surveys together. Like everyone else he started off as a probationer and later got a place on the staff. I was never a salaried member of staff.

Alan was completely deaf, as a result of meningitis at 14 – he could lip-read, but there were some people he couldn't lip-read as they didn't move their mouths enough. So I acted as his interpreter, his secretary and telephone-answerer! I went to scientific meetings and to Challenger Society meetings with him, and took notes. We lived on his salary, although I did a couple of years' part-time school teaching, to earn some money and because it was traditional for MBA wives to do some teaching!

There was a great group of us at the MBA in the mid-1950s. The MBA had become very small during the war, but the Director, Frederick (F.S.) Russell – a most determined man – was gradually getting money to appoint more staff. There were two generations of scientists, the 'pre-war' experienced ones, and younger researchers, equivalent to present-day post-docs. At that time, Ph.Ds were only just coming in – many people were taking degrees like Oxford MAs. There was a very nice group our own age – with wives and women scientists too, all friends. F.S. Russell directed each of us to a particular topic – algae, molluscs, sponges – in addition to whatever else we were doing.

How did you decide what to do next?

Once I had published two papers on polychaetes, based on my Ph.D, I began to study the breeding of intertidal lugworms. Then in 1955–56, the MBA's new research vessel Sarsia *became fully operational along the continental slope of the Bay of Biscay and new opportunities opened up. A sample of mud from about 1000 m depth revealed the presence of some unusual tubeworms with no mouth or gut – Pogonophora – which the russian expert A.V. Ivanov was already studying. I decided to concentrate on those.*

We tried to work out how these worms compared with worms in the rest of the world, and what they were feeding on. We looked at external digestion – but that didn't work as they didn't have digestive enzymes outside them. Professor Ivanov *thought that they perhaps collected food in their tube and digested it there, then absorbed it. So we looked at that, but they didn't secrete epidermal digestive enzymes. We looked into enzymes using histochemical techniques that had been developed in medicine, then along came radioactive methods – radioactively labelled proteins and amino acids. We established that these animals were very good at taking up dissolved organic material from seawater, but there had to be enough there for them to live on and the energetics didn't really work out. We had to wait until the 1980s for the solution.*

So I worked for ages on Pogonophora, and then after that it was the Mollusca, then the bivalves.

Didn't you also work on echinoderms?

Yes, back in the 1960s the Biological Record Centre began surveys of the distribution of the marine flora and fauna of the UK. The MBA offered to map echinoderm distributions using input from marine biologists and interested amateurs, especially divers. The survey itself was not published but I used the distribution data in a Linnean Society Synopsis of the British Fauna. Number 56: Echinoderms *was published in 2006. Andrew Cambell, a physiologist, became my co-author, particularly for the introductory sections, while I wrote the descriptions and drew the illustrations, based on actual British specimens.*

You seem to be very visual person?

Yes, definitely! I like drawing – I like photographs to remind me about things. I like working with images. Alan was also keen on photography – when we were doing shore work, we had a matching pair of cameras, sometimes loaded with the same kind of film, sometimes different. Alan and others at the MBA developed a deep-sea camera system, which we used at depths down to 2500 m and more on the continental slope in the Bay of Biscay, exploring the habitat of Pogonophora.

Right *Eve sorting mud on* Sarsia*, in the Bay of Biscay in 1974*

Below *A live specimen of the pogonophoran* Siboglinum fiordicum*, removed from its tube.*

(Photos: left, Alan Southward; right, Eve Southward)

At the moment I'm working through all the photographs Alan and I took after the Torrey Canyon *oil spill, adjusting the colour and the contrast, and digitising them. The idea is to have a digital bank of photographs showing the changes after the spill and in succeeding years, at all the locations we studied.*

Can you say more about the Torrey Canyon work?

We heard on the news that the ship had run aground near the Longships Lighthouse, and was breaking up, and the oil was heading towards Cornwall. The Director called us all in on a Bank Holday to tell us that the Ministry of Agriculture, Fisheries and Food had agreed that we could devote our energies to following up the effects of the oil spill. They were already planning to treat this oil with dispersant, which was really for cleaning machinery – they referred to it as 'detergent'. MBA biologists wondered what effect the detergent would have on marine organisms.

Local authorities were very keen to get beaches clean for the holiday season. The then Prime Minister, Harold Wilson, had a cottage in the Scilly Isles – he was all for burning the oil, so they bombed the wreck.

For more about the *Torrey Canyon*, see pp. 8–9.

For 18 months the MBA looked at the effects of the spill and clean-up on all kinds of marine life. Alan and I followed up the effects of dispersant along the coast. We were working with Eric Corner, a chemist who was at the MBA working on toxic paint (for a paint company). He knew all about testing the effects of toxins on animals, and had been using larvae of the barnacle Elminius modestus*. It had come from Australia, and bred all year round, unlike our local species.*

Alan and I studied the effect of detergent, and then other substances, including the oil itself – Kuwait crude, which is not as toxic as some refined oils. For every spill it's different, depending on the oil – it could be crude oil, which varies according to where it comes from, or refined oil, or aviation fuel. Diesel is very toxic. It took ages to get the oil companies to tell us what was in the dispersants.

It was quickly very obvious that where a lot of dispersant was used the animals died in far greater numbers than where there was just oil. We were in touch with the scientists in France, and by the time the oil got to the Channel Isles and then Brittany they were taking more care. The French authorities were still keen on dispersants, but the marine biologists were pretty influential and were aware of the British experience. So although the French did use dispersants, they also used a lot of hot water to disperse the oil – that also kills animals, but it doesn't hang around very long.

The Torrey Canyon *was really a landmark spill – it did a lot of damage but it told the world that it was a bad thing to use these dispersants. The manufacturers modified them, and after that they were used in smaller quantities, on ships, steps etc.*

If there is an oil spill today, the authorities are advised to try to contain the oil with floating barriers, and to put on something like chopped straw to absorb the oil so it can be collected. Of course, a lot of this was forgotten when they had the oil spill in the Gulf of Mexico – they had to learn the hard way!

Working on hydrothermal vent fauna must have been very exciting

Yes! Hydrothermal vents, with their spectacular plumed tubeworms, were discovered in 1977 on the Galapagos spreading centre. For me, the work on vent fauna came because I was already interested in Pogonophora.

Anatomically, the vent tubeworms (called Vestimentifera at that time) were obviously related to the Pogonophora, and it was still not clear how either of them obtained their nutrition. Harvard student Colleen Cavanaugh speculated on the existence of internal symbiotic chemosynthetic bacteria in these worms. And she found them! These bacteria are able to use the oxidation of hydrothermal hydrogen sulphide as their energy source. They live in a mass of tissue inside the worm body, which takes the place of the gut. Colleen got in touch with us and suggested that we should examine 'our' mud-living pogonophores for internal bacteria. Using electron microscopy, I discovered bacteria in a similar mass of tissue. In Pogonophora, the top of their tube is up in the oxygenated water, and the oxygen passes into the tentacles, is bound to haemoglobin in the blood, and carried to the symbiotic bacteria in the lower part of the body, where reduced sulphur diffuses through the tube from the sediment.

We then wondered about chemo-synthetic bacteria in other animals. We also found them in other vent fauna, including large clams with big fat gills (Calyptogena sp.), which had lots of sulphur-oxidising bacteria between or within the gills. We went on to look at intertidal animals, especially small clams. If you dig deep enough in sand or muddy sand you find a black layer, free of oxygen and full of sulphides, and – as with the tubeworms – some of the bivalves have symbiotic bacteria. So there was a long period of working on these symbionts.

What prompted the work in Vancouver?

In 1987, Verena Tunnicliffe, who was working on hydrothermal vents in the north-east Pacific, invited Alan and me to lecture at the University of Victoria, Vancouver Island. We began to study her collections of vent fauna right away. Alan retired from his MBA post in 1988 but obtained a Leverhulme fellowship which enabled us both to continue to work at the MBA and visit Victoria annually. Alan had the status of Adjunct Professor at Victoria from 1991 and we could use the facilities of the Biology Department, and work with Verena and her students, exploring the sea shore and other places.

In 1993, Verena was unable to take part in a vent cruise she had planned for the Canadian research vessel Parizeau, working jointly with the US RV Atlantis, using the submersible Alvin. She suggested I go in her place, to sort and preserve the samples, and hope I would be allowed to go on a dive. When there was a chance to go on a dive, I was taken from the Parizeau to the Atlantis in an inflatable, and given an introduction to the dark and somewhat cramped interior of the submersible, on the deck of the Atlantis. As I didn't panic, I was allowed to sleep on Atlantis overnight, and go on the dive early next morning. There was one other scientist and a calm and confident pilot. I sat on the floor and looked out through a small porthole – there was just enough light to write my own notes. I saw lots of interesting worms and took a lot of photos, most of which were usable.

Verena had a great collection of Ridgeia tubeworms from various vents. At the time it was thought that there were at least two different species, some larger and more robust than others. But I and Michael Black, who did the enzyme work, decided that these supposedly different species were actually all one, and that their body shape depended on the amount of vent sulphide available, as well as temperature, probably. Also, some of the tubeworms have very short tentacles on their plumes because they have been nibbled away by other animals and so don't grow so fast, while the ones with luxuriant plumes are free to grow.

What have been the most exciting moments of your work?

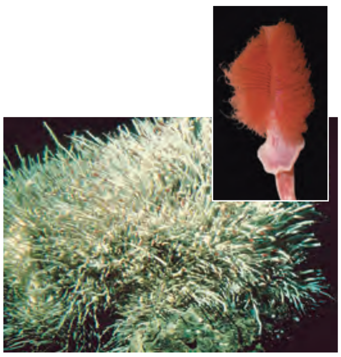
So many things! The work on symbiosis was very rewarding, but diving with Alvin was so exciting. We had cameras and recorders of the latest type and you could ask the pilot: Can we go in closer there? Can we look at the clump there? And you could also take samples. That was really exciting, gettting really close, just like you could on the sea-shore almost. You felt could almost put your hand in! Amazing.

Your skill at identifying organisms seems to have been a key aspect of your career

Yes. Although I didn't have the finances to go on cruises, I was invited on them. I looked at the animals found, I identified them and I published what I could, with or without other people. And I was sent more collections! It was a wonderful time.

Right Eve preparing to enter the submersible Alvin in 1997 (Photo: Helen Martins)

Below A clump of Ridgeia piscesae tubeworms living on the Juan de Fuca Ridge, in the NE Pacific, and **(inset)** the worm's haemoglobin-rich tentacular plumes (© Eve Southward)



Recollections of Graham Shimmield

Nick Owens pays tribute, and shares some reminiscences

It is now just over a year since we received the very sad news of the death of Graham Shimmield. Graham was a well known, highly respected, influential and much loved member of the UK marine science community, and his premature death shocked and saddened all of us who knew him.

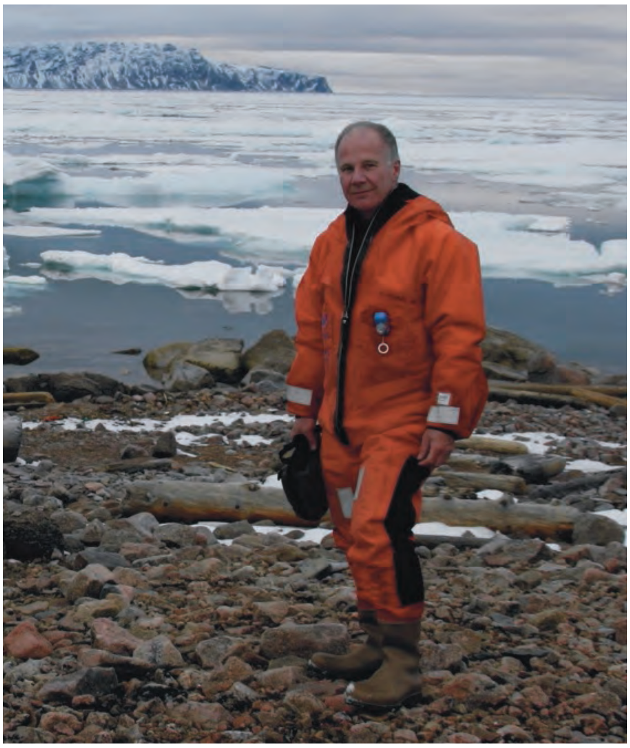
Graham was born in Trinidad in 1958. He was a geologist by training, being awarded a Ph.D in 1985 at Edinburgh University where he developed a diverse research career, becoming a Reader in Chemical Oceanography.

Graham became Director of the Scottish Association for Marine Science (SAMS) in 1996. There followed a period of extreme turbulence in the 'institutional architecture' and governance of marine science in the UK, during which Graham led the magnificent development of what we now enjoy in SAMS: an organisation approximately double the size Graham inherited; a partnership with the University of the Highlands and Islands that sees us, in the 2017/2018 academic year, deliver undergraduate, masters and Ph.D programmes to more students than we have staff (I am sure Graham would have been delighted to see this); and a thriving commercially focussed, wholly owned trading subsidiary that is growing from strength to strength.

Graham was a charismatic leader and I consider myself very fortunate to have worked so closely with him, over many years. Similar feelings were expressed very movingly by many of his friends and colleagues during a day of celebration held at SAMS on 1 December 2017 (which would have been Graham's 59th birthday), at which a large number of Graham's friends and colleagues shared their recollections.

I can't remember the first time I met Graham, but it would have been on some NERC committee. But I got to know him properly in 1992 when we went to sea together on the 'Sterna' Expedition to the Southern Ocean aboard the RV *James Clark Ross*. It was an amazing cruise: a two-ship expedition working in the Bellingshausen Sea Marginal Ice Zone (MIZ). I was Chief Scientist and Graham and Jim Smith from Edinburgh were looking at the isotope signatures of sinking particles. Our objective was to learn everything we could about the MIZ, its biogeochemistry, biology and physics. It was during a shore break acting as Antarctic base relief that Graham impressed us all with his excellent skiing abilities.

After this our paths kept crossing. We next worked together when Graham, now Director of the Dunstaffnage Lab, invited me to become external examiner for the new UHI marine science degree. I was at Newcastle University and it allowed me to visit SAMS and socialise with Graham and many who are still here. Then the Centre for Coastal and Marine Sciences (CCMS) arrived and, as one of the programme reviewers, I had the chance to take a view on the science at SAMS and spent yet more time with Graham. Soon after this, in 2000, I applied to become the Director of Plymouth Marine Laboratory and Graham was on my interview panel. He fell asleep during my talk ... this was a trait of Graham's, a result of his crazy travel schedules.



Graham on the shore of Rijpfjorden, Svalbard, during the RV* Jan Mayen *Arctic cruise in 2007

For a few months, Graham, Ed Hill and I jointly ran CCMS in the absence of a CCMS Director. Eventually we made a pitch to NERC Council about the future of CCMS, only to be told we each had a year to extract our organisations from CCMS and become independent. That evening Graham and I left together on the train to London. We were devastated, but by the time we got to London (having been sustained by a few cans of Stella!) we were in fighting mood, ready to take on the world! Graham went on to do what he did at SAMS – a difficult act to follow – and at Plymouth we created the Plymouth Marine Laboratory.

After I had left PML for BAS, Graham invited me to join SAMS Council. It was during my short stint on Council that Graham went west to the Bigelow Laboratory in Maine and repeated what he had done in SAMS; that is, he doubled the size of the laboratory, increased the staff numbers and built a campus – full of new buildings! He clearly knew how to get things done – but those of us who worked with him knew that all along.

Graham was a kind-hearted colleague and friend. He had boundless energy, a charismatic and persuasive personality and a great sense of humour: in short, someone with whom it was a pleasure to spend time with, at work or play. It was an honour to have known Graham and the world is genuinely the poorer for him not being in it.

Nick Owens is Director of SAMS

See also https://www.sams.ac.uk/t4-media/sams/pdf/publications/sams-newsletter/Ocean-Explorer-37-small.pdf
and https://www.bigelow.org/news/articles/2016-12-27.html

Decom or not to decom?

It's not just a question of cash

Kelvin Boot

The Marine Alliance for Science and Technology for Scotland (MASTS) and the Society of Underwater Technology (SUT) held the 5th Annual Decommissioning and Wreck Removal workshop in Glasgow in October 2017. Kelvin Boot reflects on the economic and environmental challenges involved and the potential solutions.

Little choice, high cost

As North Sea oil and gas fields, and the installations (rigs, platforms, pipework etc.) designed to tap the reserves, and even some of the earliest offshore wind devices, reach the end of their working lives, regulations insist that this infrastructure is safely dismantled and removed – decommissioning. Simply, the idea is to return the sea bed to the state it was in before deployment took place. The regulations governing this removal fall under the *OSPAR Convention* named from the 1972 *OSlo Convention* against dumping, broadened by the *PARis Convention*, which added land-based sources of pollution and the offshore industry in 1974; *OSPAR* came into effect in 1998.

In the heady rush to exploit North Sea reserves, it appears that decommissioning was not at the forefront of the minds of some installation designers, leaving a very expensive legacy. Just how much this is all likely to cost is difficult to pin down. One long-standing estimate suggested somewhere between £35 and £40 bn but that figure has been overhauled. A 2015 estimate by Oil and Gas UK suggested £41–46 bn, and a 2017 estimate from the UK Oil and Gas Authority has settled on almost £60 bn (at 2016 prices), but it recognises that the end cost might reach £82.7 bn, and some other groups worry that it might top £100 bn. These are eyewatering amounts and whatever the final cost, it is clear the UK tax payer will have to find around 50% of the final figure. The Oil and Gas Authority is encouraging the industry to bring those costs down by 35% through efficiencies, but the figures still represent significant costs to industry and tax payer alike.

Removal may not be the only option

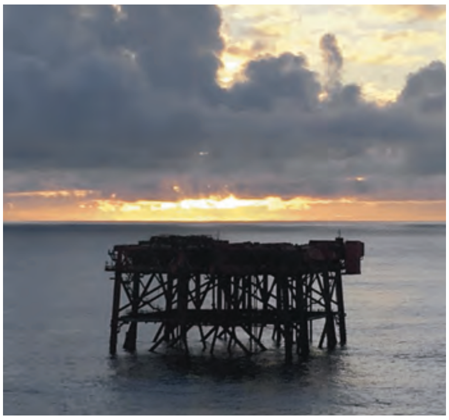
With such staggering costs on the horizon, and with the hindsight of decades of observations and experience, the burning question is no longer just about the money. As far as *OSPAR* is concerned there is a default position that the sea bed is restored to as close to its original condition as possible – there is an expectation that most of what was put in needs to come out. But does it? Huge costs aside, questions are increasingly being asked about whether it might be better to leave at least some of the structures in place. Certainly, some sub-surface structures provide homes for a wealth of encrusting marine life and the other organisms that then become attracted to the site for food and shelter. Such 'artificial reefs' are seen by many marine scientists as beneficial, adding biodiversity to what is often a fairly 'barren' sea bed. Dangers to fishing boats from hidden snags have effectively caused the areas occupied by, and surrounding, rigs and arrays of marine renewable energy devices to become *de facto* no-take zones, sanctuaries for fish, which may eventually spill over into adjacent areas, effectively seeding fish stocks beyond the forbidden perimeter. Other marine scientists, however, point to the same 'reef effect' as a negative, providing a series of stepping stones for intrusive alien species making their way across what otherwise might have been inhospitable habitat, potentially to colonise and outcompete native marine fauna and flora.

Business opportunity?

Decommissioning is also seen by many as a potential business opportunity. Much of the above-surface structure can be re-used, re-engineered or recycled, and the need for the skills to painstakingly remove installations has been heralded as an opportunity for the UK. At the forefront of building and installing platforms during the oil and gas bonanza, the UK could now occupy the vanguard of decommissioning by developing expertise on the doorstep and exporting it worldwide as other oil and gas fields become depleted and ripe for rig removal. Some industry experts are now suggesting that the savings obtained by partial removal are fairly insignificant and so not worth the debate, but there are other aspects to be considered.

One issue centres around the likelihood of damage to the surrounding environment that may be incurred during removal. The installations were built to withstand harsh conditions, so enabling efficient oil/gas extraction while providing a safe working environment for the people who live and work on them; they were not built with removal in mind. Derogations can be applied under *OSPAR* regulations allowing for installations or parts of installations to be left in place, but only in exceptional circumstances. Many people now believe that the rigid approach usually applied under *OSPAR* regulations is not fit for purpose and should be relaxed, on a case by case

Decommissioning *(left to right)* **can be a slow and difficult process** *(By courtesy MWAVES)*



basis, to minimise any collateral damage, to maintain the ecological communities that have developed on installations and, of course, to reduce the total cost of removal and avoid potential risks to those engaged in dismantling platforms.

Bringing expertise together

The quickening pace of approaching decommissioning on a large scale has stimulated various groups to enter the debate. Where previously certain interest groups have been antagonists, they are now working more closely together to gain the best expertise to address a common challenge. This has required some free thinking and an openness to other points of view.

For the last five years the Society of Underwater Technology (SUT) and the Marine Alliance for Science and Technology for Scotland (MASTS) have brought together a wide diversity of interested individuals and organisations, all aiming to face up to the 'decom' question. At the Glasgow meeting, a wide range of expertise from the decommissioning and wreck removal industries, as well as from marine science, policy, regulation and NGOs, came into the same room to discuss mutual challenges. It was obvious from the talks and ensuing questions that not only was there a willingness to share, there was also a keenness to listen.

Moya Crawford (SUT and DeepTech) started the meeting with an overview of how the different disciplines are being brought together in the Society for Underwater Technology and how that approach can be applied to the challenge of decommissioning. She pointed out that there is fantastic technology available for looking at sub-sea structures and their biology in order to improve understanding.

Removal of topside structures, and later re-use, is an ideal scenario *(By courtesy of MWAVES)*

Sally Rouse (SAMS) then outlined what the MASTS forum had been working on and what ecologists had to offer the debate. In effect was there a case to challenge or overturn the *OSPAR* decision? She reported how a group of 32 marine biologists were brought together to think purely about environmental interactions based on ecological arguments, and ignoring for that meeting at least, socio-economic, resource and carbon dioxide considerations. The three caegories addressed were: whales, birds and sharks; potential reef effects versus sea-bed disturbance; and impacts on fish and shellfish.

Taking advantage of the wealth and variety of expertise and experience in the room interactive sessions were employed: to gain more information on which baselines to use to inform decision making and to looked at the interactions that decommissioning could have with the marine environment; delegates were then given the opportunity to choose from a range of decommissioning scenarios. The results from these interactive sessions are still being analysed but it was apparent that each case would have its own merits and that there was a danger of being too simplistic. In a strong signal from the industry of the need for reliable science there were also calls for scientists to step beyond the science and express opinions. David Paterson (MASTS/St Andrews) picked up on this point, highlighting a fear that academics cannot always deliver information in a timely manner, and industry may not always share data that might speed things up. It is a highly complex area but great progress was being made through meetings such as the MASTS/SUT Decom workshops over the last few years.

A later session looked at other aspects of the 'leave in'/'take out' debate. Led by Paul Fernandes (Aberdeen) and Ben Wilson (SAMS), the breakout groups added economic aspects of decommissioning into their deliberations. These included, on the

Left ***Platform jackets, the supporting 'legs' of a platform, brought ashore for further dismantling and recycling***
Right ***Much of the material can be carefully removed and recycled*** *(By courtesy of MWAVES)*

positive side: the potential for increased fish catches; the potential for recreational diving around platform structures; the provision of linear habitat such as pipes along the sea bed, and the carbon saving resulting from leaving structures in place; and the need for environmental monitoring into the future. Other positives might be the creation of a necessary industry (and hence jobs) to manage and implement the decommissioning process, so capitalising on existing expertise and experience from the rig construction and salvage sectors.

There are balancing negative aspects to be considered, such as: the potential for future pollution as structures deteriorate; the cost of long-term monitoring; navigation risks and snagging of fishing gears; and sea-bed scouring which might affect future integrity of structures and/or impact benthic organisms. Also important was the negative public perception and the potential for a media backlash if rigs are left in place. Finding ways to avoid decommissioning might be seen as 'letting big oil off the hook', whereas removal is likely to be seen as 'doing the right thing'.

Learning from others

The real strength of the MASTS/SUT Decom workshops is that they attract high calibre people from across a wide range of industry, all willing to share their experiences. For example, when decommissioning of rigs does take place it has much in common with salvage and removal of wrecks: in neither case was it anticipated that removal would be necessary. The risks and challenges can be similar and despite some fundamental differences (e.g. salvage of wrecks often requires a much shorter time-scale than the removal of a platform), decommissioners can learn much from the salvors.

Tom Walters (Holman, Fenwick Willan LLP), for example, provided an insight into the Lloyds Open Forum contract, which effectively deflected all responsibilities to the salvor during salvage operations. The lesson for decommissioning is that not only is this a convenient way of managing a contract with a 'no win, no fee' arrangement, it also focusses onsite responsibility for operations to a single operator, thus minimising potential confusion about who does what. Command structure is all important during a complex operation in an often harsh environment and ex-US Coastguard Jim Elliot (T&T Marine Salvage) again highlighted the need for a single point of responsibility during a salvage operation, especially as under normal circumstances 'you only have 10% of the information you need' and little time to gather more. The advantage of decom over salvage is that there is always more time for planning, more time to martial relevant resources and expertise and more time to ensure the key aspects of human safety are built in from the start.

Lessons learned

Summing up the meeting, Moya Crawford pointed out that the conversations 'were now mature' and that former 'adversaries' were now talking enthusiastically to each other, largely thanks to the MASTS/SUT and similar workshops. A key lesson learned has been the importance of feedback and communication, particularly about what we do and do not know, and how we can learn from other sectors and can exchange data and utilise techniques developed in one field to facilitate better working in another. The decom challenge is global in scope and so cross-border collaborations are essential – multinational companies and international science partnerships are used to such cooperative working.

Each rig, platform, offshore wind array or other structure will have to be judged on its own merits. Many, undoubtedly, will be removed, some may stay, but each will provide an opportunity whether it be economic, social or ecological. Moya ended the meeting by stating that the UK has the intellectual resources and environmental knowledge to lead this field into the future.

Kelvin Boot is a Science Communicator, working with the Marine Alliance for Science and Technology for Scotland and other marine science organisations.

Hanging out with pteropods

Corinne Pebody

Through work in the lab since 2006, and at sea since 2010, I have been supporting the Particle Flux Group at the National Oceanographic Centre, Southampton. While studying samples collected from the Porcupine Abyssal Plain Sustained Observatory (PAP-SO) site (see Box) I have become enchanted by pteropods* – gastropod molluscs that rather amazingly have adapted to a totally pelagic life-cycle, far away from the sea bed. The shells are frequently found in sediment-trap samples and always stood out for me as beautiful structures, but when I saw the complete animals I became intrigued, and the more I looked into them, the more I became aware of their potential influence on the biological carbon pump, and the more I realised how little we know about them.

In pteropods, the muscle has evolved from a foot to move the animal over the sea floor, into a complex wing-like structure that flies the animal through the water. The wing-foot has given rise to their common name of 'sea butterfly', a name that reflects their beauty and their fragility. The shell has adapted too, becoming thinner and lighter than those of benthic molluscs. Consequently, pteropods are light enough to maintain their planktonic life, whether in the top few hundred metres in the case of most species, or in the top few thousand metres, in the case of the deep-sea species.

*Pteropod means wing-foot in Greek.

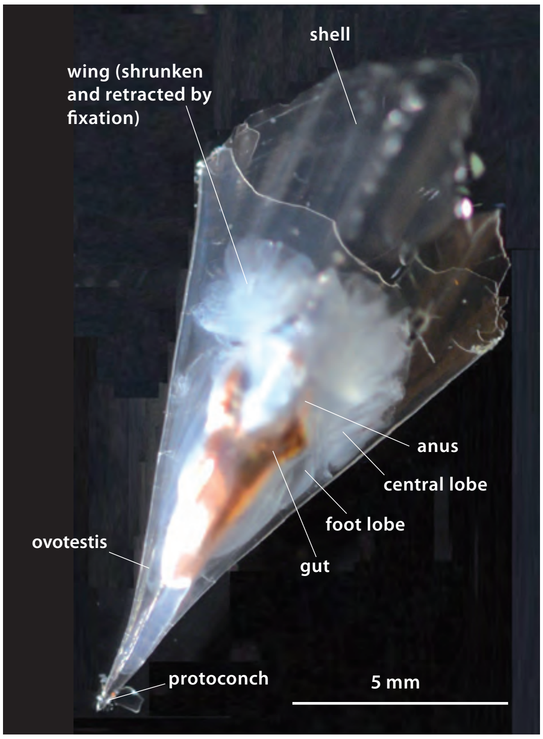
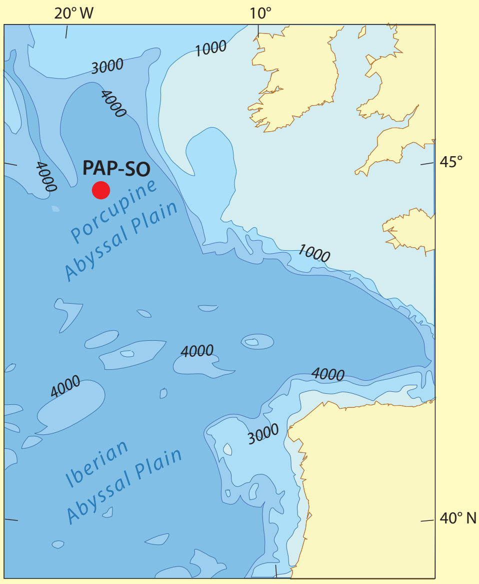


Figure 1 *The pteropod* Clio pyramidata *with body parts labelled. The anus is very near the mouth (obscured). The foot lobe has cilia to move the mucus webs towards the mouth from the gland that produces them. The ovotestis produces both ova and spermatozoa; like most pteropods,* C. pyramidata *is hermaphrodite. The protoconch is the initial shell of the larval animal..*

Figure 2 *The empty shell of a pteropod of the* Limacina *genus collected at the PAP-SO site*

The Porcupine Abyssal Plain Sustained Observatory (PAP-SO)

The PAP-SO is in the north-east Atlantic (49° N, 16° W) in a water depth of 4900 m, and has been visited regularly by NOC scientists since the 1990s. It is a site where long-term change is measured by sensors on moorings and transmitted back to NOC via satellite. In addition, seawater and benthic samples are collected both year-round and intensively on the annual research cruise. These produce in-depth analysis of many parameters from the surface to the sea bed, including the flux of sinking particles, which is measured using sediment traps. We use this information to trace the fate of carbon in its various forms, as it passes through the water column and ultimately into sea-floor sediments. For more information, see http://projects.noc.ac.uk/pap/.



The position of the PAP-SO site in the north-east Atlantic. Depth contours are in metres.

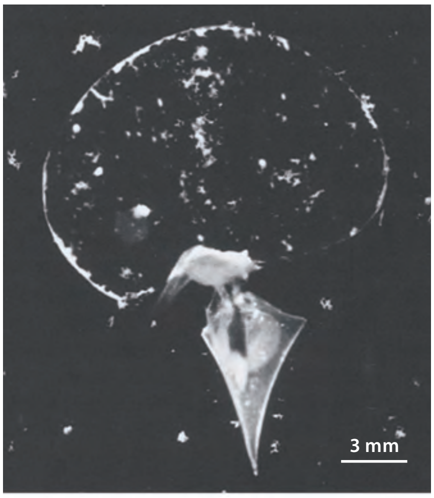
The annual research cruise and PAP-SO projects are supported by the National Environmental Research Council (NERC). The PAP-SO contributes to the EU-funded FixO3project EU312463 and there are regular collaborations at the PAP-SO site with European and American colleagues.

According to their evolutionary history and body shape, pteropods can be split into two groups: the Limacinoidea, and the Cavolinioidea. Both types occur at the PAP-SO. The cavolinids are the larger animals, with some species exceeding 10 mm in length, and where they occur, often episodically, they are a major contributor to carbon flux. The sinking empty shells rival faecal pellets as a speedy route for carbon to enter the ocean interior. Pteropod shells have (laboratory measured) sinking rates of 1.0–3.2 cm s^{-1}, so at the PAP-SO, for example, animals dying at the surface could reach the sea bed at ~4900 m in less than two days. *Clio pyramidata* (Figures 1 and 3) and *C. polita*, and several *Limacina* species (e.g. Figure 2) are often found in our deep sediment traps at the PAP-SO. Overall, there are more limacinids than cavolinids, but these animals are much smaller.

Mucus webs

These beautiful and enigmatic animals are effective swimmers and feeders. As well as the wing-shaped foot, they have developed a unique mucus web system for feeding and buoyancy regulation. The webs are three-dimensional, more spherical than a spider's web, and quicker to extrude. Once set, the webs collect small food particles, such as dinoflagellates. After the web is retracted, food items plus mucus are recovered and passed into the gut through ciliary action. Like spider's silk, the web is reused, and a new web is extruded to begin the cycle again. The web may also help the animal to maintain its depth – animals have been observed just hanging around waiting for the next meal.

Figure 3 Clio pyramidata *retracting its web, photographed at night. The object at the base of the web is the wing, seen from an unusual angle.*
(Gilmer and Harbison 1986; see Further Reading; © Springer Publishing)



Even though pteropods routinely retract and reuse the mucus, there is an energy cost to producing the webs, which consist of protein, carbohydrate and lipids. However, the webs are key to pteropods' success. They provide a hugely increased feeding area compared with the size of the shell aperture; they enable the pteropods to collect a large number of smaller food items without expending energy on swimming after prey; they allow capture of faster moving, larger prey; and they aid buoyancy, so reducing the energy expended on active swimming. Energy not used for active swimming can be used for growth and reproduction, increasing life chances for both the individual and the species.

The mucus webs catch a variety of food items, from tiny coccolithophores, through foraminiferans, radiolarians and dinoflagellates, to diatoms and even copepods and other small crustaceans. Many prey have hard shells, which are dealt with by the animal's radula (a rasping organ, consisting of a few rows, each of three teeth), and the toughest calcite tests are finally broken down in the gizzard (not visible in Figure 1).

Some species of pteropods can reach speeds of 14 cm s^{-1}, but despite the fact that pteropods have been called sea butterflies, 'flying' really only represents one of their activity states and is perhaps their response to predators, or an attempt to move horizontally to a better feeding area. Pteropods are much more likely to spend time maintaining their vertical position passively, using the mucus webs as their primary means of buoyancy (they may use ion exchange, but little is known about this in pteropods). However, although it requires a large energy input, pteropods can swim for long periods of time – for example, *Clio pyramidata* (Figures 1 and 3) can swim for eight hours after capture (personal observation).

Pteropods, marine snow and the carbon cycle

At the PAP-SO we collect sinking particles and by measuring the amount of carbon sinking to depth, we can estimate the carbon dioxide that is absorbed by the oceans and locked away on geological time-scales. Pteropods are an important part of this flux because their shells are made of calcium carbonate and this, along with the organic carbon in their internal organs, is transported to the deep sea, when any uneaten animals ultimately sink to the sea floor. Far more common, however, are the uneaten remains of animals, and fragments of shell.

Mucus webs are abandoned if the web becomes tangled with the pteropod's faecal matter, which is a risk because the animal's anus and mouth are so close together (cf. Figure 1). The webs are also abandoned if the animals perceive a threat. The sticky balls of mucus become part of the rain of sinking particles, often referred to as 'marine snow', and thereby contribute to the biological carbon pump. The mechanism is not known exactly, but the sticky web may become a kernel to which particles continue to adhere so forming a larger aggregate. This aggregate may be fed upon by micro- and mesozooplankton, so keeping carbon in shallower water for longer. Cyclopoids (small copepods which typically feed on aggregates of marine snow) have been observed near or attached to pteropod webs and faecal pellets. Alternatively, the aggregates may become larger and heavier, possibly by being ballasted with diatoms and other heavy phytoplankton, and sink out of the surface water faster. In this way, the webs contribute to export of carbon into the ocean interior where it can be out of contact from the atmosphere for more than 100 years) or, if they reach the sea floor (where organic remains can sometimes be seen as a carpet of green/brown snow) they could become buried and incorporated into sea-floor sediments, so being locked away from the atmosphere over geological time-scales.

Figure 4 *A sediment trap being deployed at the PAP-SO site. The containers at the bottom move around every 2–4 weeks, allowing each in turn to receive material collected by the funnel, so providing an observational time-series.*

Predation

Some pteropod species undergo diurnal vertical migrations, feeding near the surface at night and sinking to deeper water (where they defecate) in the daylight hours, before swimming upwards again at twilight. This effectively moves carbon deeper into the ocean where it is respired and released by the animal before it swims up again to feed. Migration away from sunlit surface waters reduces the amount of time when the pteropods could be seen by visual predators, such as chaetognaths (arrow-worms), and even marine mammals, including whales. Pteropods are an important component of the diet of fish, including some commercially important species, for example, cod, salmon, herring and mackerel.

It seems that pteropods are also the favourite diet of other molluscs. Heteropod molluscs (which have reduced their shells even more than pteropods) are significant predators. These cousins are highly effective visual predators feeding on pteropods and other zooplankton. Gymnosome molluscs (pteropods without shells, sometimes known as 'sea angels') have also adapted to capture other species of pteropods.

Pteropods and ocean acidification

Pteropods have been identified as a group likely to be negatively affected by ocean acidification (see Further Reading) because their aragonite shells are more soluble than shells made of calcite, the more stable form of calcium carbonate. Therefore, it is important that we identify current distributions of individual species of pteropods before further change occurs. Some species may also make useful indicator organisms, allowing us to track the effects of ocean acidification. Current knowledge of pteropod distribution is patchy, but it is being updated and existing records are being synthesised into informative datasets (see Manno *et al.* in Further Reading).

We have been recording the numbers of pteropods in sediment traps at the PAP-SO in the north-east Atlantic for many years and perhaps can provide a benchmark for the changes that we are expecting to see as the climate changes and waters both warm and decrease in pH. For example, the pteropod *Diacria trispinosa* (Figure 5) is at its northern limit at the PAP-SO, where we only see it episodically. More regular and/or more numerous catches would suggest its distribution is changing. Certainly a rare visitor becoming more common further north could only be measured by long-term monitoring provided by established time-series such as that being recorded at the PAP-SO. We will continue to catch pteropods in our sediment traps and plankton nets to find out more about the lives of these entrancing animals and to measure their currently underestimated contribution to the oceanic carbonate system and the global carbon cycle.

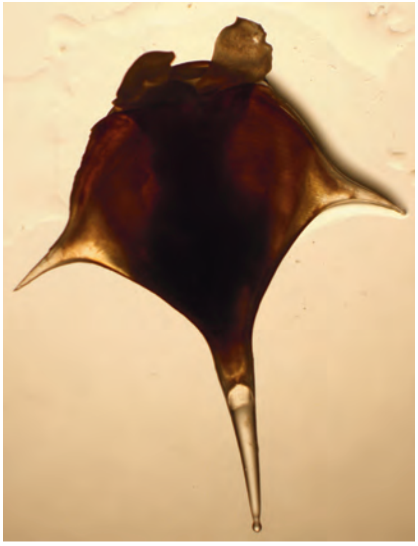


Figure 5 Diacria trispinosa, *with its three-spined shell, captured at the PAP-SO. The wings (shrunk due to fixation) can be seen protruding from the top of the shell. This species can reach 12 mm long.*

Further Reading

Bednaršek, N., J. Možina, M. Vogt, C. O'Brien, and G.A. Tarling (2012) The global distribution of pteropods and their contribution to carbonate and carbon biomass in the modern ocean. *Earth Syst. Sci. Data* **4**, 167–86.

Feely, R.A., C. L. Sabine, K. Lee, W. Berelson, J. Kleypas, V.J. Fabry and F.J. Millero (2004) Impact of anthropogenic CO_2 on the $CaCO_3$ system in the oceans. *Science* **305** (5362), 362–6. doi: 10.1126/science.1097329

Gilmer R.W. and G.R. Harbison (1986) Morphology and field behaviour of pteropod molluscs: feeding methods in the families Cavoliniidae, Limacinidae and Peraclididae (Gastropoda: Thecosomata). *Marine Biology* **91**, 47–57.

Hicks, N. (2013) Ocean acidification – much more than a hot research topic. *Ocean Challenge*, **20** Summer, 3–4.

Lalli, C.M. and R.W. Gilmer (1989) *Pelagic snails*. Standford University Press, pp. 58–166.

Manno, C. and 18 others (2017) Shelled pteropods in peril: Assessing vulnerability in a high CO_2 ocean. *Earth-Science Reviews*, **169**, 132–45.

Orr, J.C. and 26 others (2005) Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* **437**, 681–6. doi:10.1038/nature04095

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Coral Cay Conservation and Citizen Science

How volunteers are contributing to marine conservation in the Philippines

Tom Dallison and Tessa Dawson

Through citizen science, volunteers have for many years contributed to research and data-gathering for terrestrial, coastal and marine conservation programmes, which mitigate and remediate impacts on ecosystems. With a little training, anyone can become a 'citizen scientist' and support global efforts towards the preservation of our natural world. The most common question asked by conservation-minded advocates, and amongst institutional networks, is 'Is citizen science effective?' The answer is 'Absolutely, when done properly!' With competition increasing for funding opportunities, reductions in available funding, and unprecedented impacts on natural ecosystems, never have citizen scientists been more valuable in the world of conservation.

In 1986, Coral Cay Conservation (CCC) adopted a 'citizen science' approach, and has undertaken critical conservation efforts in an array of countries around the world, from Belize and Montserrat, to Cambodia and Papua New Guinea. CCC focusses on a maximum of two locations at any one time, aiming to provide resources to help sustain livelihoods and alleviate poverty. Through the protection, restoration and management of coral reefs, CCC works closely with local stakeholders in a bottom-up approach to conservation.

CCC, as a member of the International Coral Reef Initiative, has a global reach through sharing critical data and best practice with partnering organisations. It also plays an important role in raising general awareness of the threats to coral reefs. With 2018 being declared the Third International Year of the Reef (IYOR 2018) – a global effort to strengthen awareness and promote conservation action – there has never been a greater drive to protect coral reefs.

Figure 1 ***(a)*** *A map of the Philippines and* ***(b)*** *Southern Leyte Province with Sogod Bay at the centre. The Coral Cay Conservation project site is located in the Municipality of San Francisco on the south-eastern side of the bay.*

Since 2002, CCC has focussed its efforts in the Philippines within Sogod Bay

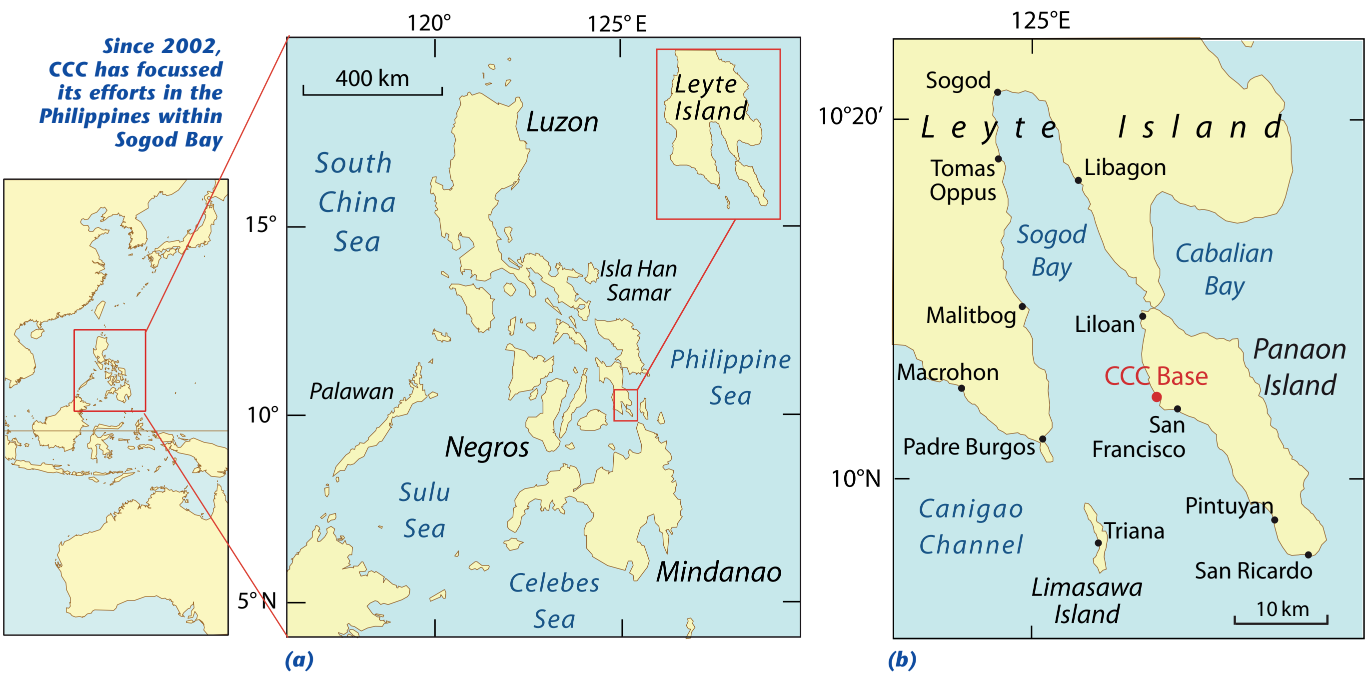


Figure 2 The Coral Triangle (red outline) is an area of 6 million km^2 that spans the Philippines, Indonesia, Malaysia, Papua New Guinea, Timor Leste and the Solomon Islands.

(Outline produced using data supplied by the Coral Triangle Initiative)

Since becoming established in the Philippines in 1996, CCC has been driving forward conservation, working alongside governmental bodies, non-governmental organisations (NGOs) and local stakeholders, promoting sustainable practices and collecting valuable data. Currently, CCC is located in Barangay Napantao (i.e. Napanto Village), San Francisco Municipality, Southern Leyte, and it focusses efforts within Sogod Bay (Figure 1(b)), through The Southern Leyte Coral Reef Conservation Project, established in 2002.

Coral Cay Conservation in the Philippines

The Philippines lie within the Coral Triangle (Figure 2), the most biodiverse marine hot-spot on the planet, where 26 000 000 ha (260 000 km^2) of coastal waters support 2 700 000 ha (27 000 km^2) of coral reef (9% of the global total), 76% of the world's coral species, six of the seven marine turtle species, and over 6000 species of marine fish. With almost 1 000 000 registered fishers and over 40 million people residing within 30 km of a coral reef, the marine and coastal resources of the Philippines face extremely high pressures. Over 98% of coral reefs in the Philippines are classified as endangered, with the greatest threat being overfishing. Over 70% of the threatened reefs are being harmed by destructive fishing practices, such as the use of dynamite or cyanide. These problems resulted in *The Philippine Fisheries Code of 1998* (Republic Act No. 8550) which states that 15% of municipality waters should be protected through '… fish refuge [*sic*] and sanctuaries', commonly referred to as 'Marine Protected Areas' (MPAs).

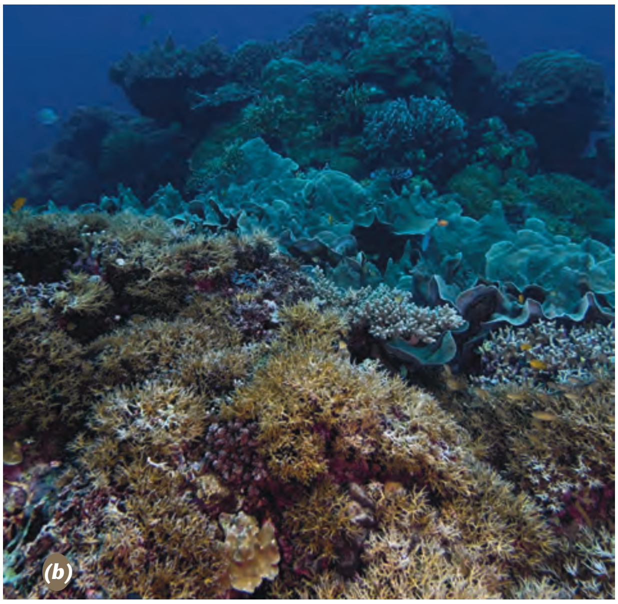
The Coral Triangle is the global centre of coral species diversity

According to the most recent data, in 2013 there were a total of 1183 registered MPAs in the Philippines, with 59 designated in Southern Leyte. Currently, within Sogod Bay there are over 23 established MPAs covering about 170 ha, and ranging in size from 2 to 45 ha. Sogod Bay has 132 km of coastline shared by 11 municipalities, each with their respective barangays, and is an important fishing ground with over 5000 tonnes being caught in 2015. Whilst the reefs of Sogod Bay are, in many places, in good condition, signs of overfishing are widespread, with low abundances of commercially important fishes such as parrotfish and groupers.

The majority of MPAs within Sogod Bay are small scale, with stakeholders using a range of management approaches based on the MPA's aims, which reflect the fauna and flora present, cultural and traditional values of local communities and the social and economic drivers of the region. For example, Barangay Napantao Fish Sanctuary (a 9 ha MPA) (Figure 3) incorporates a 5 ha No-Take Zone where

Figure 3 The Napantao Fish Sanctuary is a No-Take Zone that lies within the Marine Protected Area associated with the Barangay Napantao coral reef, known as 'House Reef' by Coral Cay Conservation.

The MPA associated with the reef incorporates a No-Take Zone where extraction of any organism is forbidden



The complex coral reef habitat within the MPA supports a highly diverse ecosystem

Figure 4 *Thanks to the protection provided by the MPA and the No-Take Zone, the Barangay Napantao coral reef displays amazing biodiversity.* ***(a)*** *A shoal of fusiliers (Caesionidae) cruise over the complex reef structure composed mainly of branching, foliose (lettuce) and massive (boulder) forms of coral.* ***(b)*** *The highly complex reef structure drives biodiversity on coral reefs through the provision of niches. Branching forms, such as* Acropora *spp. (foreground), are more structurally complex and faster growing than massive forms such as* Porites *spp. (in the background).*
(Photos by courtesy of Jon Cabiles)

all extraction gears and boat access are prohibited by by-laws, enforced through fines. The No-Take Zone is enforced by means of a designated Bantay Dagat (Marine Guard), and tourism activities such as SCUBA diving and snorkelling generate income for the local community through user-fees.

The value of citizen scientists in Sogod Bay

Citizen scientists are an essential component of CCC's efforts in the Philippines, and are integrated into CCC's three-tiered approach: data-collection, outreach and education, and capacity-building.

Management recommendations are submitted to CCC's main project partners, the Provincial Government of Southern Leyte and Municipal Government of San Francisco, for implementation. Since 2013, CCC's Southern Leyte Coral Reef Conservation Project has focussed on the establishment, assessment and monitoring of MPAs, providing the local stakeholders with the necessary skills, tools and knowledge to sustainably manage their own marine resources, for the health of Southern Leyte's natural systems and, by extension, those who depend on them.

CCC's most successful capacity-building initiative is the Scholarship Scheme, which provides national Filipinos who show a passion for conservation the opportunity to undertake a four-week training course free of charge. Through funding, volunteers have enabled the provision of technical training and education to over 130 CCC Scholars, many of whom have continued into higher educa-

Once trained, volunteers join CCC's survey teams

Figure 5 ***(a)*** *Coral Cay Conservation's citizen scientists head out to begin an intensive ecological survey of the Barangay Napantao coral reef.* ***(b)*** *When diving, the CCC science team are surrounded by an awe-inspiring array of wildlife, which can sometimes get in the way!* *(Photos by courtesy of (a) Sarah Mynott and (b) Jon Cabiles)*

Figure 6 *Coral Cay Conservation's citizen scientists learn to dive, develop surveying skills and collect ecological data.*

tion, acquired conservation-focussed careers and established NGOs based in Southern Leyte.

Without citizen scientists and dedicated staff, stakeholders cannot be inspired and empowered, data cannot be collected, nor MPAs established. However, it is crucial that CCC's efforts are efficient, effective and based on robust data, and this is ensured by CCC's Skills Development Programme. Volunteers are trained to at least PADI SCUBA Advanced Open Water diver, as well as in *in situ* survey techniques and species identification, followed by validation studies and exams. CCC can therefore be confident that the data collected and supplied to project partners are robust, and that conservation management can be undertaken with conviction.

To date, CCC volunteers have facilitated the complete ecological mapping of Sogod Bay, providing baseline data for future management whilst contributing to the assessment, establishment and monitoring of over 15 small-scale MPAs within the bay. Barangays that wish to establish an MPA will request, via the Provincial Government of Southern Leyte, that CCC conduct an assessment within their coastal waters. The survey methods practised, and data collected, during assessments of proposed MPAs not only provide spatial analysis but also focus on temporal trends. Assessing an MPA's effectiveness is an important factor in ensuring success; such assessments focus, for example, on coral species composition and fish community structure, whilst providing the opportunity for resource managers to practise adaptive management.

Findings from the Napantao MPA

Data collected by volunteers (Figure 6) from six permanent transects, between 2013 and 2015, were analysed in order to assess the efficacy of the established Barangay Napantao MPA. Data regarding the abundance and diversity of fishes and invertebrates were collected in combination with information about anthropogenic impacts and substratum composition using underwater visual census techniques, through an augmented Reef Check protocol (see http://www.reefcheck.org). Six 100 m 12 m-deep transects were surveyed per annum, equalling a total of 36 transects throughout the survey period. Each 100 m transect was subsequently split into four 20 m sections separated by 5 m gaps where no data were recorded, to ensure the collection of four independent datasets. To enable the assessment of the MPA's performance, comparative studies had to be conducted, so three of the surveyed transects were located within the boundaries of the MPA and the remaining three located outside. From 2013 to 2015, CCC analysed temporal and spatial variations in abundance, biomass, species richness, *S*', as well as the Shannon diversity index,* *H*' (which describes the relative abundances of individual species within a community) (Figure 7) .

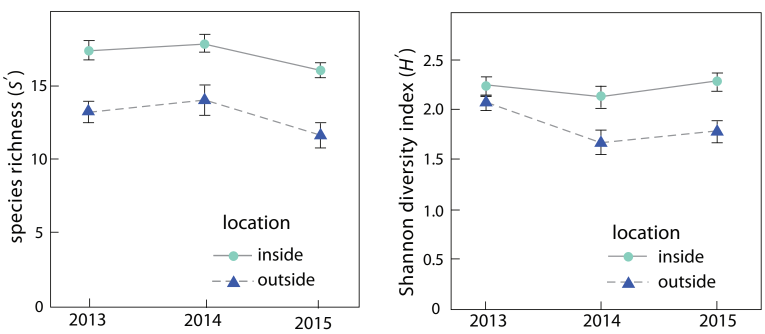
From the analysed data, it was apparent that the Napantao reef is experiencing adverse impacts, resulting in a significant decline in fish abundances both inside and outside the MPA. From 2013 to 2015, despite the species richness of fish communities inside and outside the MPA seeming to decrease (Figure 7(a)), there was no statistically significant trend; however, a significant decrease in the Shannon diversity index, *H*', was recorded outside of the MPA (Figure 7(b)). Over the survey period (2013–15), both *S*' and *H*' were significantly greater inside the MPA's boundaries than outside (Figure 7(a) and (b)).

Data collected by CCC's citizen scientists are used to advise project partners on the implementation of conservation strategies

* The Shannon diversity index is a measure of the 'evenness' of communities within an ecosystem. For example an ecosystem with large numbers of one particular species and very few of any other, would have a low Shannon Index.

Figure 7 *Data on the diversity of fishes obtained through underwater visual census surveys from two locations, one inside and one outside of the established MPA boundary, from 2013 to 2015:* ***(a)*** *Mean species richness (S') and* ***(b)*** *Shannon diversity index (H'). Error bars indicate the standard error of the mean.*

During 2013–2015 the diversity of fish species was greater inside the MPA than outside



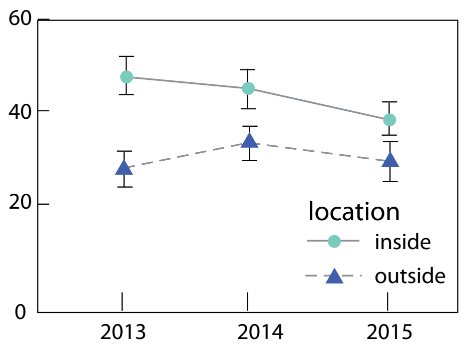
Of the commercially important fish families, parrotfish were dominant in terms of abundance throughout the sample period, contributing the greatest standing biomass in comparison with grouper and snapper. However, the parrotfish populations were composed of small, sexually immature juveniles, with a lack of large (> 40 cm) adults, and demonstrated a significant decrease in abundance, alongside snapper.

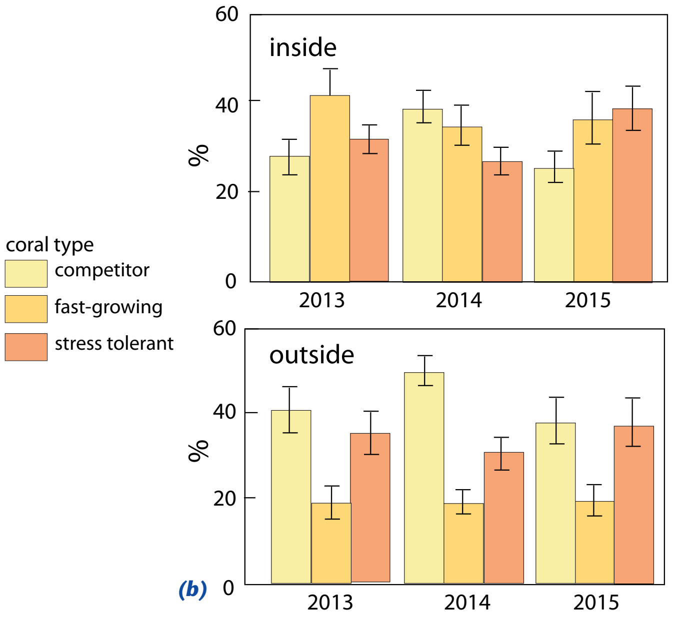
Whilst indicator invertebrates† such as lobsters, giant clams, and Triton's trumpets demonstrated no temporal trends or spatial variation over the survey period, data on scleractinian (i.e. hard) corals were indicative of adverse stressors. Inside the MPA, scleractinian coral cover decreased by 9% from 48% to 39%, but throughout the survey period was significantly greater than that recorded outside the MPA (Figure 8(a)). Furthermore, in 2013, inside the MPA, coral composition was dominated by *Acropora* spp. which confer high habitat complexity, so driving biodiversity, but between 2014 and 2015 there was a 12% increase in cover by stress tolerant corals, such as massive *Porites* spp. (Figure 8(b)), reducing habitat complexity and suggesting stress, a possible cause of the observed decreases in fish abundance. No significant trends were observed in coral morphologies inside or outside of the MPA from 2013 to 2015, but each year fast-growing corals were significantly more abundant inside the MPA than outside (Figure. 8(b)). The observed decrease in reef health through a decrease in coral cover, and an increase in stress tolerant coral species, is corroborated by a significant decrease throughout out the survey period in the abundance inside the MPA of those butterflyfishes that are obligate corallivores (i.e. feed only on coral polyps).

†An indicator species is an organism whose presence, absence or abundance reflects a specific state of the studied environment. They can reflect both natural and anthropogenic influences (e.g. storms and overfishing, respectively.)

Figure 8 ***(a)*** *Mean percentage composition of scleractinian hard coral recorded inside and outside the Barangay Napantao MPA from 2013 to 2015.*
(b) *Further analysis resulted in hard coral being categorised into three sub-categories: competitor corals (e.g.* Fungia *spp. – free-living mushroom corals), fast-growing corals (e.g.* Acropora *spp.), and stress tolerant corals (e.g. massive corals). Error bars indicate the standard error of the mean.*

During 2013–15 hard coral cover within the MPA was consistently greater than that outside

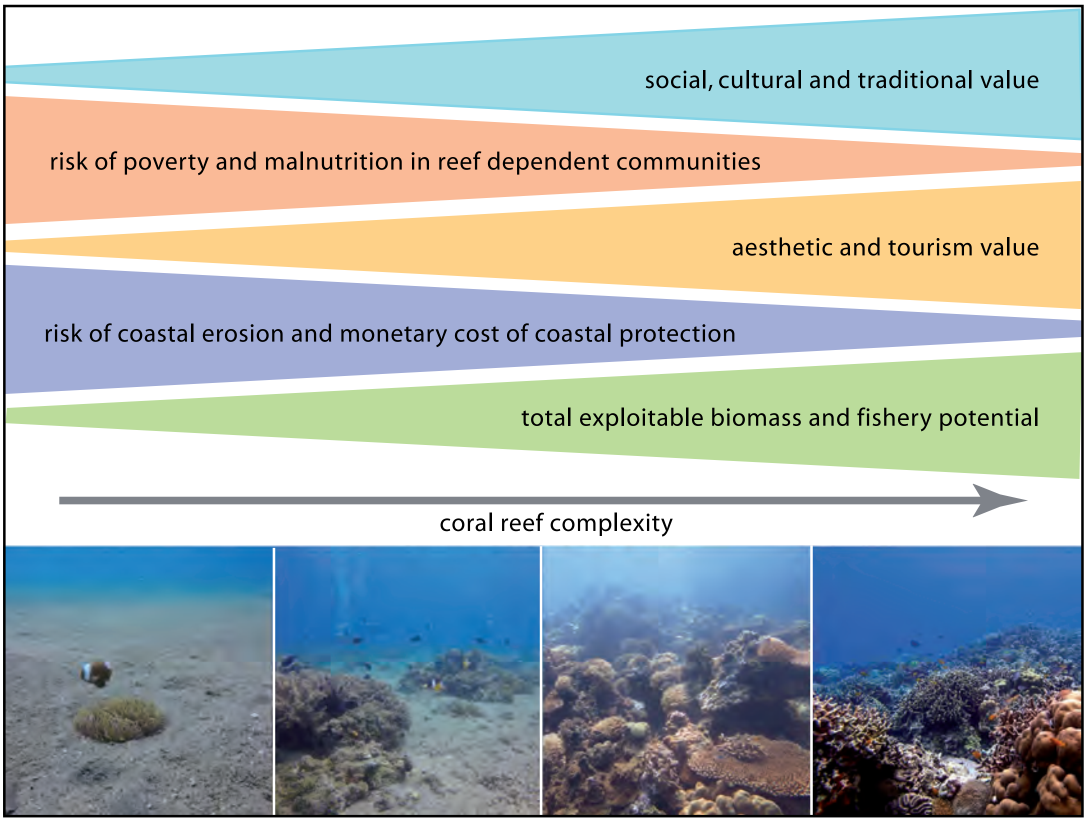




The data collected by CCC's team of volunteers throughout the survey period are indicative of an MPA that is buffering the protected part of the reef against species decline but is failing to increase the productivity of the fishery. The protected portion of the coral reef is more complex in benthic structure than areas that are unprotected, indicating received benefits from the MPA, driving biodiversity and supplying a range of ecosystem services (Figure 9, opposite). However, further temporal monitoring may indicate significant negative trends. It is evident, furthermore, that Napantao reef is displaying signs of acute and chronic impacts, so continued monitoring will be required.

The actions and efforts of CCC volunteers enabled the assessment of the Napantao MPA, and the fomulation of recommendations, such as increasing the size of the protected area and ensuring that there is a bottom-up approach to MPA designation. This would be in addition to better enforcement of the MPA regulations, as the low abundance and small size of commercially important species indicated that poaching and overfishing were prevalent. Signs of overfishing emphasised the need for greater efforts in community engagement and transparency at the local user-group level, to empower local fishers throughout the MPA designation process – a model that has proved to be successful in the establishment of other small-scale MPA. The reported data also enabled CCC to call for the development of regional consortiums throughout Southern Leyte in order to engage communities on an inter-municipality level, with the main goal of establishing Sogod Bay as a region-wide marine reserve that practises marine spatial planning and an ecosystem approach to fisheries management.

Whilst emphasis is often placed on high-profile, externally funded conservation programmes to provide key results and novel approaches, the Southern Leyte Coral Reef Conservation Project, and the documented study of Napantao MPA, is a clear demonstration of the value of citizen



Coastal communities benefit from high levels of complexity in a coral reef ecosystem, as seen within the Barangay Napantao MPA

Figure 9 *Diagram to show how the intangible 'goods and services' provided by a coral reef ecosystem increase with the increasing complexity of the reef ecosystem, while certain problems faced by coastal communities may be reduced.*

scientists to conservation. The Southern Leyte Coral Reef Conservation Project demonstrates that with continued support, long-term projects are able to achieve significant outcomes, and by providing opportunities and training to a range of people, citizen science programmes enable individuals to challenge a global issue.

Further reading

Bellwood, D.R., T.P. Hughes, C. Folke and M. Nyström (2004) Confronting the coral reef crisis. *Nature*, **429**, 827–33. doi: 10.1038/nature02691

Dallison, T. and A. Ferguson (2017) Assessing the efficacy of small-scale Marine Protected Areas in the Philippines: A triennial case study, Barangay Napantao 2013–2015. Coral Cay Conservation.

Edgar, G.J. and 24 others (2014) Global conservation outcomes depend on marine protected areas with five key features. *Nature*, **506**, 216–20. doi: 10.1038/nature13022

You can read all of CCC's reports at https://www.coralcay.org/scientific-research/scientific-reports/

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A new era for ocean observation

AUVs coupled with chemical sensors will enhance our understanding of the marine environment

Peter J. Statham

Our current understanding of the inter-linked biological, chemical and physical processes occurring in the ocean interior is mainly based on one-dimensional snap-shots from vertical profiles obtained from conventional instrument packages and analysis of collected samples. When sufficiently spatially intensive, this approach can give a much improved knowledge of distributions of biological and chemical properties and, potentially, processes (as in the case of the international GEOTRACES programme studying trace elements and their isotopes in the ocean). However, more detailed information on short-term changes in space and time, and underlying processes, still remains elusive. Higher resolution information is particularly important if we wish to follow large-scale biological impacts on a seasonal basis, or short-term physico-chemical influences including mixing and stratification in shelf waters. Newly developed autonomous underwater vehicles (AUVs), coupled to innovative *in situ* chemical analyser systems, are now beginning to provide this type of high-resolution data, and are set to become important devices for research into oceanic processes occurring over a range of time- and space-scales (Figure 1).

Autonomous underwater vehicles are rapidly becoming mainstream tools in oceanographic research, and provide important extra dimensions to the process studies that are undertaken on conventional research ships. Typically varying in size from 1 to 10 m in length, these devices can carry instruments that are moved vertically and horizontally through the ocean interior. There are several types, including simple floats that move vertically up and down in the water column and are carried along by currents (e.g. *Argo* floats, Figure 3), gliders that use a buoyancy change engine, depth control and wings to glide from one location to another (e.g. Slocum gliders Figure 2(a)), and fully autonomous propeller-driven systems such as *Sentry* (Figure 2(c)) and *Autosub* (Figure 4). Many countries, including Japan and France, are actively developing and using such vehicles.

Early autonomous vehicles faced significant challenges, including having enough energy, keeping fouling of sensors at bay, and successfully navigating below the surface away from GPS and satellite communication. These limitations are gradually being overcome. The latest generation of AUVs such as *Autosub Long Range* (*ALR*) will have a depth capability of 6000 m and mission duration of 6000 km. Examples of new environments explored using AUV technology include under ice sheets, and around hydrothermal systems on the deep ocean floor. AUVs thus provide excellent opportunities for carrying chemical and other measurement systems for observing key biogeochemical variables on space- and time-scales that were previously impossible using conventional ship- or mooring-based systems (Figure 1).

On a similar time-scale to the evolution of AUVs, there have been major developments of *in situ* biogeochemical sensors, which allow biogeochemical properties of seawater to be measured directly, in the ocean, rather than on board ship after the water sample has been retrieved from the ocean. Use of fluorescence quenching* for measuring dissolved oxygen is now an accepted and reliable technology (as in Aanderaa oxygen-sensing optrodes). There are also fluorescence detectors for estimating concentrations of coloured dissolved organic matter, chlorophyll and suspended particulate matter, and inclusion of these detectors is standard for many current glider-based investigations.

Developments of *in situ* measurements of key chemical compounds, and in particular nutrients essential to oceanic plant growth, have taken longer to come to fruition. As an example, nitrate analysis has taken two principal approaches: (1) measuring direct optical absorption by nitrate, and (2) use of *in situ* colorimetric analysers based on conventional laboratory chemistries (see Further Reading). The optical UV absorption analysers are compact, but extracting the data requires involved processing to separate the nitrate signal from those of other absorbing species in solution. Analysers based on globally accepted colorimetric methods have been developed around microfluidic architectures,† and have been used in freshwater and coastal systems on buoys or water-front structures. The designs of these devices have needed to overcome a range of challenges including energy stor-

*This technique uses a fluorescence indicator whose luminosity is reduced (quenched) by molecular oxygen, and this reduction can be related to oxygen concentration.

†Microfluidic architectures are linked channels a few 10s or 100s of microns across, typically enclosed in a plastic block to form the basis of a 'lab-on-chip'. Mixing of solutions occurs primarily through diffusion and results in coloured compounds that can be detected.

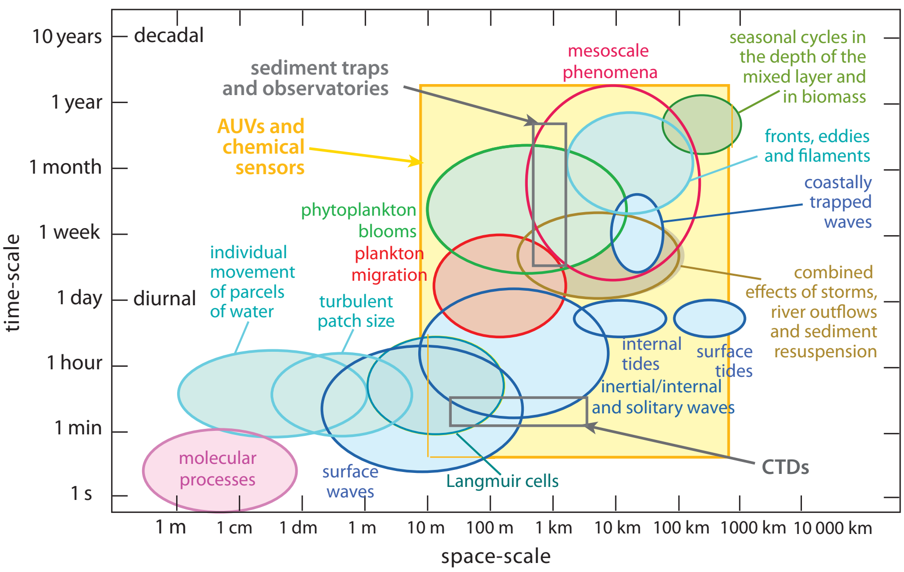

Figure 1 *Space–time domains for major biogeochemical and physical processes in the ocean. The yellow boxed area shows the range of scales that AUVs coupled to chemical sensors can cover, compared with the range of scales that can be covered by CTDs (conductivity–temperature–depth instrument packages deployed from a ship) and moored sediment traps and observatories mounted on vertical cables attached to the sea floor. (After Tokar and Dickey, 2000)*

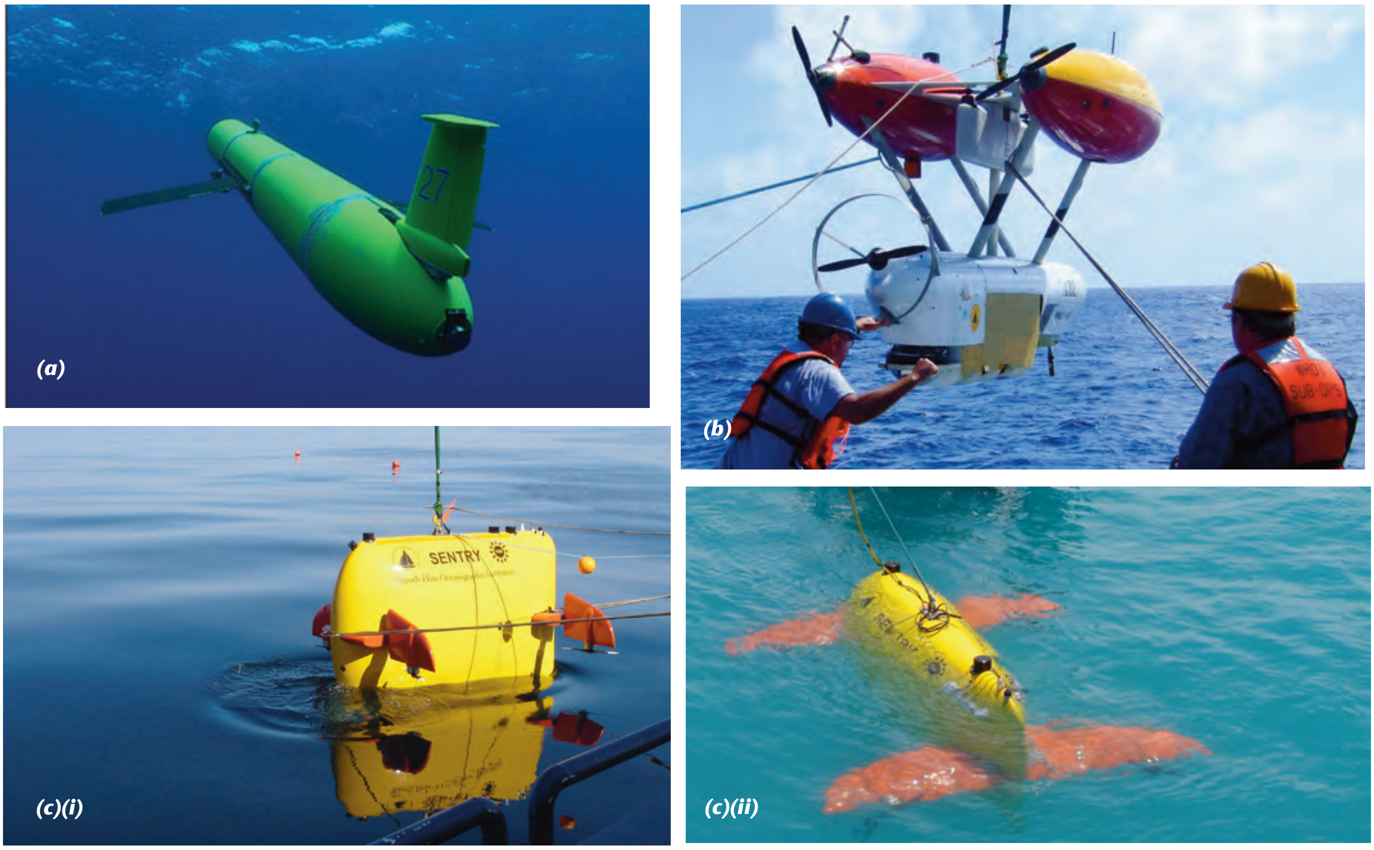

Figure 2 *Examples of some AUVs.* ***(a)*** *A* Slocum *buoyancy-driven glider.* ***(b)*** *Woods Hole's* Autonomous Benthic Explorer *(ABE), designed to investigate deep ocean environments such as hydrothermal vents.* ***(c)*** ABE*'s successor,* Sentry*,* ***(i)*** *at the start of deployment,* ***(ii)*** *with its 'glider wings' extended. (Photos by courtesy of: (a) Rutgers University; (b) Dana Yoerger; © WHOI and (c) Chris German; © WHOI)*

age, biofouling, reagent stability and pump reliability. A range of other techniques are also being developed for important biogeochemical parameters, and offer exciting possibilities.

Use of chemical analysers on AUVs

The parallel developments of AUVs and *in situ* chemical analysers are now starting to converge, with their combination being used in a variety of applications to marine biogeochemistry. In addition to the challenges associated with *in situ* analysers in general, there are many technical challenges to the use of chemical analysers on AUVs; these include physical size, the limited energy available on small AUVs and gliders, and the impact of changing temperature and pressure as AUVs move through the water column. Several of these challenges are difficult to solve and in part explain why the technology has taken so long to come to fruition. However, a series of recent applications of this combination of technologies demonstrates the power of the approach.

An example of an existing AUV with potential to have chemical sensors added is the *Argo* float; this device can regulate its depth but otherwise moves passively with water masses through the ocean. Deployment of *Argo* floats (Figure 3) has been very successful and in March 2017 there were 3985 *Argo* floats scattered through the ice-free ocean basins (http://www.argo.ucsd.edu/How_Argo_floats.html), each with the task of providing information on temperature and salinity in the upper 2000 m of the water column; many *Argo* floats are already equipped with oxygen and other sensors. The float cycle starts with a descent to a target depth of 1000 m; the float then drifts for typically nine days, before descending to 2000 m; finally, it records temperature and salinity profiles as it returns to the surface, where

Figure 3
An Argo float being launched into the Indian Ocean
(By courtesy of CSIRO)

data are transmitted back to the shore laboratory.

Argo floats are gradually expanding the range of measurements made to include nitrate using optical absorption as well as oxygen. An example of significant new biogeochemical knowledge that came from a nitrate sensor on an *Argo* float was the importance of sporadic nutrient inputs to the surface ocean in the central North Pacific. These inputs are essential in supporting the phytoplankton growth observed in this area that was previously unexplained. Some *Argo* floats have been modified to measure particulate organic carbon in the Southern Ocean (see Further Reading).

In a very recent development, nutrient analysers based on microfluidic architectures are being further reduced in size to fit within a glider shell (only about 300 mm in diameter). Here classical benchtop chemistry has been shrunk and automated; the chemicals needed to react with the nutrient of interest (e.g. nitrate or phosphate) are pumped into a cell where they mix and the absorbance of the resulting colour is directly proportional to the concentration of the nutrient. For information about these and related developments, see the Further Reading.

Metals have also been measured by *in situ* chemical analysers coupled to AUVs. Dissolved manganese was measured by an *in situ* chemical analyser in Loch Etive, Scotland, by formation of a coloured complex and its measurement on board the AUV *Autosub*. Measurements were made continuously on along- and across-loch transects at different depths, and the calibrated data combined to build a detailed 3D distribution of manganese at that time of year (Figure 4). The detail revealed substantial gradients in manganese, both vertical and horizontal, that would have been impossible to see by conventional means (sampling by water bottles on vertical lines, and subsequent analysis in the shore laboratory). In total, nearly 10 000 measurements of dissolved manganese were made over the course of a week, in comparison to less than 100 measurements made over the previous decade using conventional methods. Other *in situ* metal measurement systems are being developed and deployed as instrument sensitivity and concentrations in the water allow.

Future directions and new challenges

New technologies applied to AUV design and operation, including improved power supplies and navigation, will allow longer and deeper missions. These developments coupled with exciting advances in chemical measurement systems (e.g. fluorometric and molecular biology) will provide new opportunities to study the interior of the ocean at time- and space-scales not previously possible. Examples of future applications include basin-wide mapping of active hydrothermal vent sites along ocean ridge systems and, through use of a fleet of AUVs in one area, improving the temporal and spatial resolution of measurements. For example, improved resolution would be useful in the study of shelf and slope processes impacting nutrients, metals and phytoplankton growth. Whilst AUVs with sensors can greatly improve our knowledge of ocean processes, there will still be a need to work on research ships at sea, as complex experiments involving multiple measurements, bulky equipment and human intervention are beyond the scope of current autonomous systems.

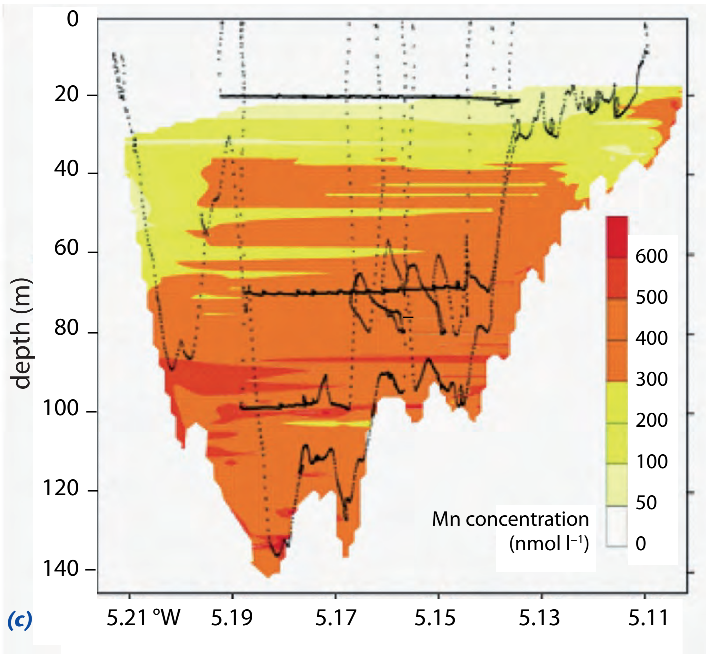

Figure 4 ***(a)*** Autosub *fitted with an on-board dissolved manganese analyser,* traversing *Loch Etive on the west coast of Scotland.*

(National Oceanography Centre, Southampton)

(b) *The dissolved manganese sensor (inside the clear oil-filled tube) fitted within* Autosub.

(c) *Distribution of dissolved manganese (Mn) in Loch Etive, obtained using* Autosub *fitted with the on-board dissolved Mn analyser. Black dots represent individual measurements.*

In addition to challenges with improving the capabilities of the AUVs and sensors currently in use, there is the issue of 'Big Data'. An AUV running one instrument at one measurement per second, for a deployment of 30 days, produces 2.6 million data points. Normally, there is more than one instrument being deployed and in addition there are all the logged data on the position and performance of the AUV itself. After careful quality control the challenge is to present and analyse the data so that information on the processes of interest can be easily followed. Suitable approaches are being developed now, and from the early work done we can see that exciting times lie ahead for ocean scientists using this new generation of observation tools!

Acknowledgement

I am most grateful to Professor Gwyn Griffiths for comments on an earlier version of this article.

Further reading

AUVs

ARGO: http://www.argo.ucsd.edu accessed March 2017.

Biever, C. (2006) Swarms of subs set to uncover the ocean's mysteries. *New Scientist* online. http://www.newscientist.com/.../mg19125715-800-swarm

Blidberg, D.R. (2001) The development of autonomous underwater vehicles (AUVs): a brief summary. http://ausi.org/publications/ICRA_01paper.pdf

Glenn, S., Kohut, J. and O. Schofield (2015) Continuing the Challenger Mission – addressing global problems of the Antropocene. *Ocean Challenge*, **21** (1), 16–18.

Sensors

Beaton, A.D, C.L. Cardwell, R.S. Thomas, V.J. Sieben, F.-E. Legiret, E.M. Waugh, P.J. Statham, M.C. Mowlem and H. Morgan (2012) Lab-on-chip measurement of nitrate and nitrite for *in situ* analysis of natural waters. *Environmental Science and Technology* **46** (17), 9548-56. doi: 10.1021/es300419u

Johnson, K. S. and H. Claustre (2016) Bringing biogeochemistry into the Argo age, *Eos*, **97**. https://doi.org/10.1029/2016EO062427. Published on 8 November 2016.

Mowlem, M., G. Benazzi, D. Holmes, H. Morgan, C. Haas, M. Kraft, A. Taberham, V. Chavagnac, P.J. Statham and P. Burkill (2006) Micro system technology for marine measurement. In *Proceedings of IEEE/MTS Oceans '06 Conference, Boston MA, September 18-21, 2006.* NJ, USA, IEEE.

Nightingale, A.M., A.D. Beaton and M.C. Mowlem (2015) Trends in microfluidic systems for *in situ* chemical analysis of natural waters. *Sensors and Actuators B: Chemical*, **221**, 1398–1405. doi: 10.1016/j.snb.2015.07.091

Prien, R.D. (2007) The future of chemical *in situ* sensors. *Marine Chemistry* **107**, 422–32.

Rudnick, D.L., R.E. Davis, C.C. Eriksen, D.N. Fratantoni and M.J. Perry (2004) Underwater gliders for ocean research *Marine Technology Society Journal* **38** (1), 48–59.

Applications of AUV sensors

Bishop, J.K.B. and T.B. Wood (2009). Year-round observations of carbon biomass and flux variability in the Southern Ocean. http://onlinelibrary.wileycom/doi/10.1029/2008GB003206/full Accessed 16 August 2017.

Johnson, K.S., S.C. Riser and D.M. Karl (2010) Nitrate supply from deep to near-surface waters of the North Pacific subtropical gyre. *Nature* **465**,1062–5, doi: 10.1038/nature09170. See ftp://oceane.obs-vlfr.fr/pub/claustre/Bio_argo/biblio-g%C3%A9n%C3%A9rale_compl%C3%A8te%20Copy.enlp/biblio-g%C3%A9n%C3%A9rale_compl%C3%A8teCopy.Data/PDF Johnson-2010-Nitrate%20supplyfrom-0455259136/Johnson-2010-Nitratesupplyfrom.pdf Accessed 16 August 2017.

GEOTRACES, www.geotraces.org accessed July 2017.

Statham, P.J. *et al.* (2005) Spatially complex distribution of dissolved manganese in a fjord as revealed by high-resolution *in situ* sensing using the autonomous underwater vehicle *Autosub*. *Environmental Science and Technology* **39** (24), 9440–45.

Tokar, J.M. and T.D. Dickey (2000) Chemical sensor technology: current and future applications, pp.303–29 in *Chemical sensors in oceanography*, edited by M.S. Varney. Gordon and Breach, Amsterdam.

For more information see https://www.ocean-sci.net/special_issue13.html Accessed 16 August 2017.

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Advances in Marine Biogeochemistry (AMBIO) VIII

SAMS were pleased to host the eighth Advances in Marine Biogeochemistry (AMBIO) conference in Oban – the first time the meeting of this Challenger Society forum, which facilitates networking for early career researchers, had been held in Scotland.

In September 2017, more than 45 delegates from over 20 institutes came from as far away as the Laboratoire d'Etudes en Géophysique et Océanographie Spatiales in France and the Institute for Marine and Antarctic Studies in Hobart. They gathered to present their work and honour the career of Professor Peter J. Statham on his retirement from active research.

Key themes on the first day covered biomineralisation, global nutrient and carbon cycling, deep sea ecosystems and 'lab on a chip' sensors. The second day, dedicated to Prof Statham, focussed on iron cycling (one of his special research topics), organic carbon, mass spectrometry, and marine policy and knowledge exchange. Prof. Statham delivered an inspirational keynote presentation identifying the changing nature of marine biogeochemistry and future opportunities for the next generation of marine biogeochemists.

Seona Wells (Aberdeen) was awarded the best student poster prize for her work on gelatinous zooplankton, with Kyle Mayers (Southampton) winning best student presentation for his enthusiastic talk on coccolithophore populations in shelf-sea systems. The early career awards went to Amber Annett (Southampton) for her exciting presentation on trace metals in the Antarctic Peninsula, and Robyn Tuerena (Liverpool) for her poster on the role of tidal mixing in euphotic zone nutrient cycling.

The final event for AMBIO VIII was a robotics and sensors workshop, where over 20 attendees shared a stimulating discussion and exchange of ideas, led by Julie Robidart and Socrates Loucaides.

After the conference dinner on the final night, delegates were treated to a traditional Scottish experience, as they were escorted to a ceilidh by a kilted bagpiper!

AMBIO VIII received sponsorship from Planet Ocean, SAGES, the Marine Alliance for Science and Technology for Scotland (MASTS) Marine Biogeochemistry Forum and the Challenger Society.

AMBIO IX will be held in the autumn of 2019. For updates in coming months, see the Challenger Society website.

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SEACAMS

Collaboration between marine research and business in Wales

Colin Jago and Michael Roberts

SEACAMS (Sustainable Expansion of the Applied Coastal and Marine Sectors) is a project that helps businesses (predominantly small and medium-sized enterprises) to access data, facilities and expertise in the research community in order to help the commercial marine sector in Wales develop and expand. Conceived and directed from the Centre for Applied Marine Science in the School of Ocean Sciences at Bangor University, SEACAMS is a collaboration with marine scientists at Swansea University. Initiated in 2010 and due to end in 2019, SEACAMS has been part-funded by the Welsh European Funding Office, drawing on the European Research Development Fund, at a total cost of £40M. Its *modus operandi* is via collaborative projects with business partners: both SEACAMS and business bring resources to a joint project to address issues and problems, and provide solutions, so enabling the business to progress and expand its operations. These resources include a fleet of research vessels including the 36 m RV *Prince Madog*, the largest university-owned research vessel in the UK (she is jointly owned and operated by Bangor University and P&O Maritime). Collaboration and dissemination underpin the SEACAMS ethos: SEACAMS is not a consultancy and all data and results are publicly available.

SEACAMS has developed in two phases; phase 1 (2011–15) operated in businesses across a broad spectrum of marine areas (e.g. marine renewable energy, marine aggregates, submarine cabling, environmental impact assessment). In this phase, SEACAMS worked on more than 100 collaborative research projects with many companies; these companies estimate that inward investment to Wales resulting from SEACAMS projects will reach £50M by 2020. In phase 2, currently running, SEACAMS is focussing on marine renewable energy.

Marine renewable energy

Marine renewable energy is a hot topic in Wales. With its high-energy tidal and wave regimes, the shelf and coast of both north and south Wales provide ample potential for a range of developments to exploit marine renewable energy. In 2014, the Crown Estate, which owns the territorial sea out to 12 nautical miles, announced six new wave and tidal current Demonstration Zones in the UK, where locally based organisations manage and sub-let parts of the sea bed to a range of wave and tidal stream developers. These demonstration zones are in areas specially chosen for their suitability for test and demonstration activities. The remit of Demonstration Zone managers is to attract developers for the zones, to undertake essential preparatory work such as obtaining necessary licenses and consents from regulatory bodies, provide grid connectivity and help develop a local supply chain.

Two of the demonstration zones are in Wales: the West Anglesey Demonstration Zone, for tidal stream energy (i.e. energy extracted from tidal currents, by means of turbines fixed to the sea bed) and the South Pembrokeshire Demonstration Zone, for wave energy. In addition, parts of the Welsh coast have been favourably assessed as potential locations for developments exploiting high tidal ranges. These will be tidal lagoons in which large volumes of water will be captured at high tide, and then released to drive turbines and generate electricity (i.e. the same principle as employed using tidal barrages across estuaries).

Tidal stream energy Efforts to harness tidal stream energy are focussed off west Anglesey and are being managed by Menter Môn through their Morlais project (Morlais means 'voice of the sea'). The Demonstration Zone is 37 km^2 in area and is generally based around the promontory of Holy Island – it is this geographical feature which leads to the acceleration of flows, so that fast tidal current speeds are generated in this region. Eight tidal energy companies are currently working in the Zone. Tidal stream development has been considered for other sites around Wales, including Ramsey Sound (Figure 1), though this is currently halted.

Tidal range energy The large tidal ranges along the coasts of both north and south Wales coasts make them prime targets for the development of tidal lagoon installations. The proposed sites in Wales and adjacent areas could generate up to 9% of the UK electricity need. A pilot lagoon in Swansea Bay being developed by Tidal Lagoon Power is at an advanced stage of planning. Further, larger lagoons are planned for Cardiff, Newport, Bridgwater Bay in Somerset, Colwyn Bay and west Cumbria, north of Workington.

Wave energy The zone for wave energy off Pembrokeshire, some 90 km^2, is managed by Wave Hub.* The wave resource in the area is 19 $kW\,m^{-1}$ and the zone has the potential to support the development of wave energy arrays with a generating capacity of up to 30 MW for each project.

*For more about Wave Hub, see pp. 4–6 in *Ocean Challenge*, **19** *(Spring)*

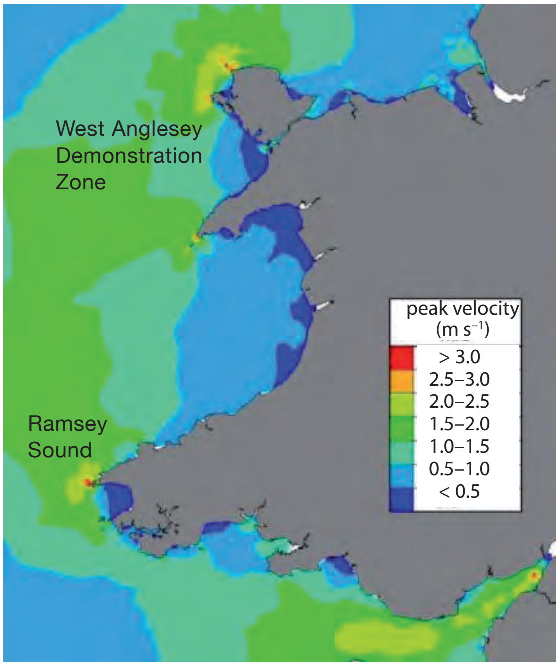


Figure 1 *Hydrodynamic model showing the peak tidal velocities in the waters around Wales. The West Anglesey Demonstration Zone and Ramsey Sound are potential sites for tidal stream energy projects.*

(SEACAMS Research Offiice)

Figure 2 *An ADCP being lowered to the sea bed from the RV* Prince Madog*. This is part of the range of equipment made available to companies participating in SEACAMS.*

The SEACAMS operation

SEACAMS runs collaborative research projects with companies working in marine renewable energy. These companies are small, with limited expertise and resources in oceanography and marine science. SEACAMS assists companies in three areas of their operation:

- Quantifying the hydrodynamic resource through observation and modelling (e.g. Figure 1).
- Optimising site-selection for turbines and engineering installations.
- Assessing the environmental impact of installations on local and regional spatial scales and short to decadal time-scales.

SEACAMS provides data and expertise to quantify mean, peak and extreme energy conditions and frequencies, wave–current interaction, turbulence properties, etc.; all of these are needed by companies to assess turbine performance and efficiency. While individual companies are concerned about local conditions, and require high temporal resolution site-specific data, SEACAMS can also provide a regional perspective of hydrodynamics that is equally important. By definition, developments in marine renewable energy are generally in high-energy regimes which are challenging for both researchers and businesses. Consequently, these areas have been somewhat neglected by marine scientists. SEACAMS modellers have therefore generated high-resolution model simulations of the tidal regime in the West Anglesey Demonstration Zone using data from sea-bed-mounted 5-beam Acoustic Doppler Current Profilers (ADCPs) (Figure 2) which provide information about current velocity throughout the whole water column, as well as about waves and turbulence, using techniques pioneered at the School of Ocean Sciences, Bangor University.

Companies also need high-resolution imagery of the sea bed. Information on sea-bed type and morphology is essential for accurate modelling of hydrodynamics but is also vital for optimising the location of engineering installations and for assessment of their environmental impact. To this end, SEACAMS has been collecting a large database of multibeam echo-sounder imagery of areas of the sea bed around Wales. Thus far, areas of the sea bed equivalent to the area of Anglesey have been surveyed (Figure 3). These data are used to generate visualisations of sea-bed geometry which are valuable to a wide range of stakeholders (e.g. Figure 4, right). Where needed, bathymetry is supplemented by sub-bottom profiling. Multiple surveys of the West Anglesey Demonstration Zone (Figure 4, left) have shown that the sea bed is much more heterogeneous than was suspected, with areas of bedrock (as expected in a high-energy region) but also large fields of dynamic sand waves. The migration of sand waves, and associated sediment transport processes, are potential threats to turbine operation so these features are of particular interest.

Figure 3 *Extent of SEACAMS multibeam echo-sounder data around the coast of Wales.*

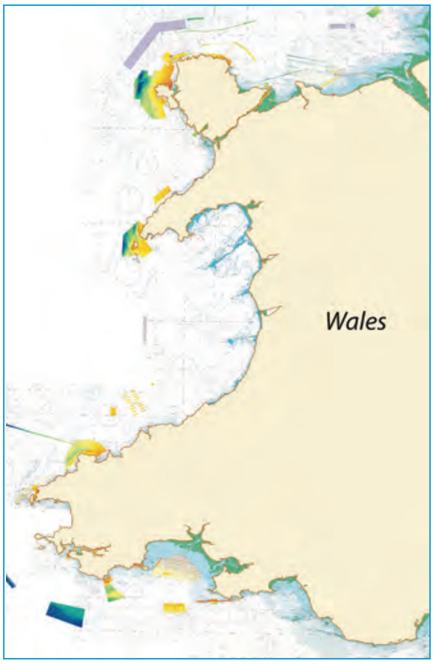
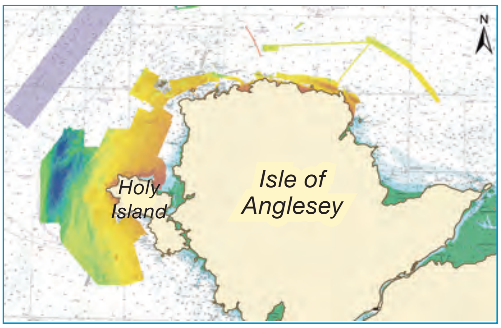


Figure 4 ***Below left*** *SEACAMS multibeam echo-sounder data coverage of the West Anglesey Demonstration Zone and waters off northern Anglesey.* ***Right*** *Multibeam echo-sounder data for the waters around Holy Island, overlaid on Google Earth Imagery.*



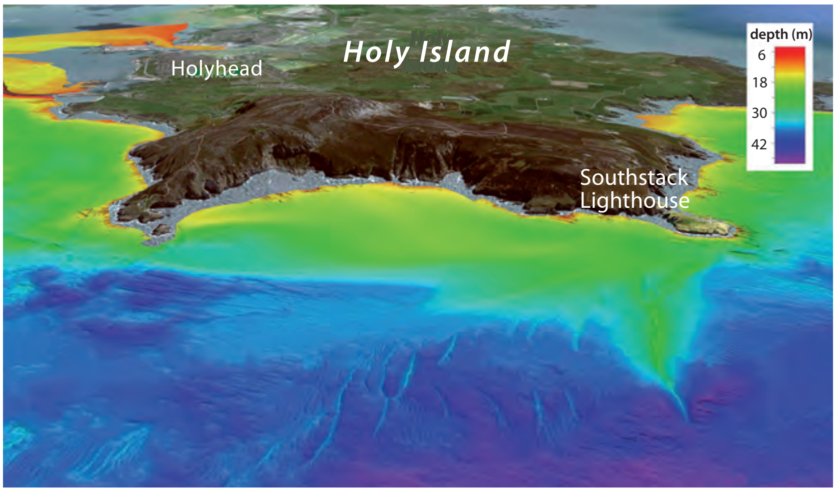


Figure 5 ***Left*** *Saballeria alveolata reef situated in Llanddulas, the site of a potential tidal lagoon* ***Right*** *SEACAMS Research Officer Tim D'Urban-Jackson monitoring the reef using a Terrestrial Laser Scanner*

Perhaps the major factor that engages the interest of companies working in marine renewable energy is the environmental impact of their installations. State-of-the-art environmental impact assessment underpins the planning and consenting frameworks operated by environmental regulators such as Natural Resources Wales. But since marine renewable energy installations such as tidal lagoons have an operational life-span of more than 100 years, environmental impact assessment is challenging. SEACAMS is working on projects that consider impacts on coastal sediment transport, morphodynamics (Figure 5), water quality (Figure 6), benthic organisms, fish migration, and marine mammal migration.

Figure 6 *Manager Susan Allendar and Caroline Duce undertake water-quality testing in the SEACAMS Laboratory.*

New data infrastructure for Welsh marine science

A frequently stated complaint to SEACAMS from the commercial marine sector is that the data infrastructure in UK marine science is designed for the research community rather than for businesses. SMEs with limited resources encounter considerable difficulty in sourcing data in a form that they can readily use. SEACAMS is therefore spearheading two interlinked initiatives.

Data gathering: Welsh Integrated Marine Observation System (WIMOS)

WIMOS is a network of coastal and marine observatories, comprising instrumented platforms and moorings providing real-time data. Platforms are standardised with respect to instrumentation and sampling protocols. The instrumented platforms, located on the sea bed between the shoreface and inner shelf, are not fixed in permanent locations; they are moved according to operational or strategic need (Figure 7). They interrogate benthic and near-surface boundary layers using ADCPs, pulse-coherent profilers, acoustic and optical suspended sediment sensors (ABS, OBS, LISST), and acoustic sensors for water column turbulence (ADVs). Supplementing the platforms are moored sea-bed-mounted 5-beam ADCPs (mentioned earlier) and surface wave buoys providing real-time wave characteristics via the CEFAS WaveNet internet site. WIMOS is set up to provide the data that marine businesses need in the locations that interest them.

Data provision: Integrated Marine Data and Information System (iMarDIS)

iMarDIS is a centralised data portal currently under development in SEACAMS. It is a data acquisition centre for banking, manipulating and providing data to researchers, businesses and other stakeholders: a one-stop shop for data, tools, services, advanced models, and access to networks.

Observational data collected through WIMOS is streamed live and direct to iMarDIS, which is the portal for all stakeholders requiring access to data and services. It differs from traditional databases in concept, purpose and delivery. iMar-DIS is being co-designed with the commercial sector to provide co-development, co-delivery, and co-evaluation of data, information and knowledge, so providing solutions tailored to the site in question.

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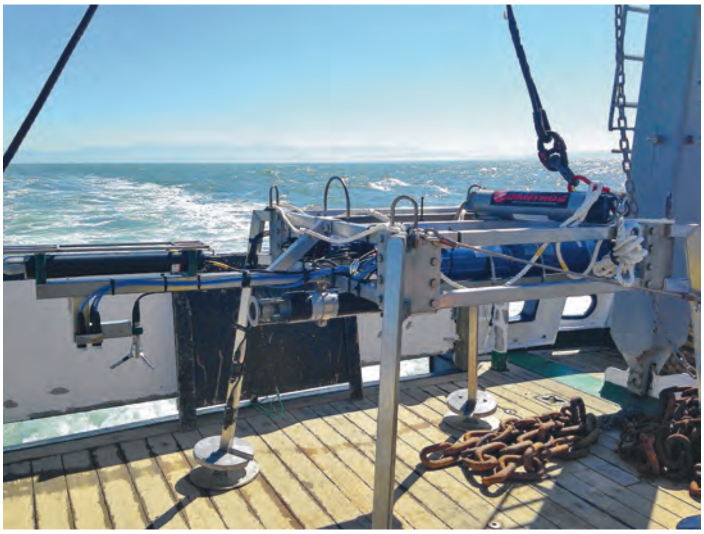
Figure 7 *WIMOS instrument frame in transit to deployment location*



A 'cranky little vessel': The story of HM steam vessel Lightning

Part 3: Events, dear boy, events!

Tony Rice

Britain's upper crust 1960s Prime Minister, Harold Macmillan, is said to have responded to a journalist who asked what he thought might blow any government's policy off course with the words 'Events, dear boy, events!' clearly meaning any unforeseen circumstance. Whether or not SuperMac actually uttered the words is debatable, but their veracity has been attested to many times, not least in recent turbulent months in the UK. But 'twas ever so, and this third part in the *Lightning* story takes us back to unexpected events in the early months of 1827 which had a major influence on the story of our little vessel and of the navy in general.

In the previous episode,* we left *Lightning* at Deptford in the autumn of 1826, having just returned from escorting vessels to Cronstadt in Russia for the funeral of Tsar Alexander I. The article included the text of a letter sent by her engineer, John Chapender, to his ultimate boss, the navy's senior civilian engineer, Simon Goodrich, in which Chapender signed himself as 'Acting engineer of H.M. Ship *Lightning*'. But this was not, strictly speaking, accurate because, at that time, *Lightning* and her fellow naval steam vessels were not included in the *Navy List*, the official list of all naval officers and the ships in which they served. Instead, the steam vessels had a definitely subsidiary status compared with the navy's traditional sailing vessels and were therefore not entitled to the prefix 'HMS'. And they were still staffed largely by civilian personnel, including Chapender himself. This situation was about to change drastically, but for political rather than technological reasons.

The early months of 1827 saw the effective demise of two of the most prominent figures on the British establishment scene. The first, only five days into the New Year, was the death of Frederick, Duke of York, the second son of George III and therefore, until his departure, the first in succession to the throne then occupied by his elder brother, George IV. This put Frederick's younger brother William Henry, Duke of Clarence, into the monarchical hot seat, so to speak. Though the death of George IV three years later and William's accession to the throne must have been the most momentous event in his life, it was the second unforeseen event in 1827, the resignation of the Tory Prime Minister, Lord Liverpool, in February, that was so important for the *Lightning*.

Robert Banks Jenkinson (1770–1828), Second Earl of Liverpool, had been in power as Prime Minister since 1812, when his predecessor, Spencer Perceval, had been shot dead by a bankrupt Liverpool broker as he entered the lobby of the House of Commons. During his 15 years in power, Liverpool had been able to unify the old, reactionary, and new, reforming, Tories at a critical time, a difficult task not unknown in our own day. For the whole of that time, the most powerful naval post in the land, that of First Lord of the Admiralty, had been held by Robert Saunders Dundas, Second Viscount Melville and very definitely an old style Tory. When Liverpool was struck down with a stroke and had to resign from the premiership, Melville and several of his like-minded colleagues, including the Duke of Wellington, refused to serve under Liverpool's replacement, the progressive Tory, George Canning, who formed an administration with the help of the Whig opposition – a bit like the coalition government of Tory David Cameron and Lib. Dem. (a.k.a. Whig) Nick Clegg. A new First Lord of the Admiralty was needed to replace Melville, but with the post carrying with it automatic membership of the Cabinet the choice was fraught with political difficulties and the last thing Canning wanted was an opinionated politician in the post. Clearly, some lateral thinking was required.

A cunning plan.

The 57 year-old Canning was widely experienced and politically astute. With the support of the King, he came up with what must have seemed to him to be a Black-Adderish 'cunning plan': if the old Mikado-esque sounding post of Lord High Admiral, without Cabinet membership, were to be resurrected and offered to the Duke of Clarence, the king-in-waiting, a number of problems would be solved at a stroke.

From the time of Henry VIII to the end of the 17th century, the overall responsibility for running the nation's navy had usually been delegated to one person, the Lord High Admiral, appointed by, and directly responsible to, the monarch. But as successive parliaments sought to reduce the power of the monarchy, there were several more or less abortive attempts to replace the role of Lord High Admiral with a board of Admiralty 'Commissioners'. Finally, in 1702, Queen Anne reluctantly abolished the post of Lord High Admiral and replaced it with the new post of First Lord of the Admiralty who, as head of the Board of Admiralty, was responsible to parliament rather than to the monarch. And that is the way things stayed until Canning's ruse resurrected the post, but with its powers severely curtailed, to solve his immediate problem. For although the new Lord High Admiral would have nominal control of the navy, and any decisions would be announced as emanating from him, the appointment would also involve the creation of a Council to advise him. He would be unable to take any executive decisions without the Council's approval, and even when he was at sea he would be accompanied by a member of the Council who would have to confirm his orders. These restrictions would render the Duke of Clarence more or less powerless, and control of the navy would effectively lie with the Cabinet, just as Canning wanted. The appointment would also strengthen Canning's royalist credentials, appealing particularly to his more conservative Tory colleagues. Finally, resurrecting the old post appealed to George IV's sense of history and would enable him to flatter and reward his brother at little or no cost or inconvenience to himself.

Accordingly, in April 1827, shortly after Canning came to office, Prince William Henry, the Duke of Clarence, was offered the Lord High Admiral post and, despite the restricted powers, accepted it with alacrity. And no wonder, for he was basically a thwarted Royal Naval officer who had unsuccessfully sought employment for decades. On the insistence of his father, George III, William had entered the Royal Navy as a midshipman in 1778

**Ocean Challenge*. Vol 22 (1), pp.28–31.

at the age of 13. Despite the obvious risks of disease, injury or even death in a naval career, the King saw the discipline and training of a naval officer as the ideal preparation for the duties of a royal prince, particularly one with little chance of acceding to the throne; after all, at that time he had two brothers ahead of him in the line of succession. Moreover, service in the navy would remove him from the sphere of influence of his two elder brothers whose dissolute lifestyles were already giving their parents cause for concern. In the event, the navy had its own less than regal influence on William's behaviour, and within a few years he could, and frequently did, drink, swear and whore with the best, or worst, of his naval companions. But the important point, as far as the *Lightning* story is concerned, is that he took to the naval life like the proverbial duck to water to such an extent that he was eventually to be known widely, and rather affectionately, as the Sailor King. So in 1827, at the age of 62 and having been essentially unemployed for almost thirty years, William was delighted with his new job and tackled his duties, and privileges, with some enthusiasm.

As it transpired, Canning was destined to witness the results of the appointment for only a few short weeks. His health was already deteriorating when he came to office and he died on 8 August 1827, ending the United Kingdom's shortest Prime Ministerial term which had lasted only 119 days. And his successor, Viscount Goderich, lasted only a couple of weeks longer as Premier before he was forced to resign in January 1828 to be replaced by the much more extreme Tory, the Duke of Wellington. But throughout these political ups and downs the Duke of Clarence was able to enjoy his new role as the navy's titular boss, partly with fairly lavish socialising but also by introducing some important and much-needed reforms.

The Lord High Admiral

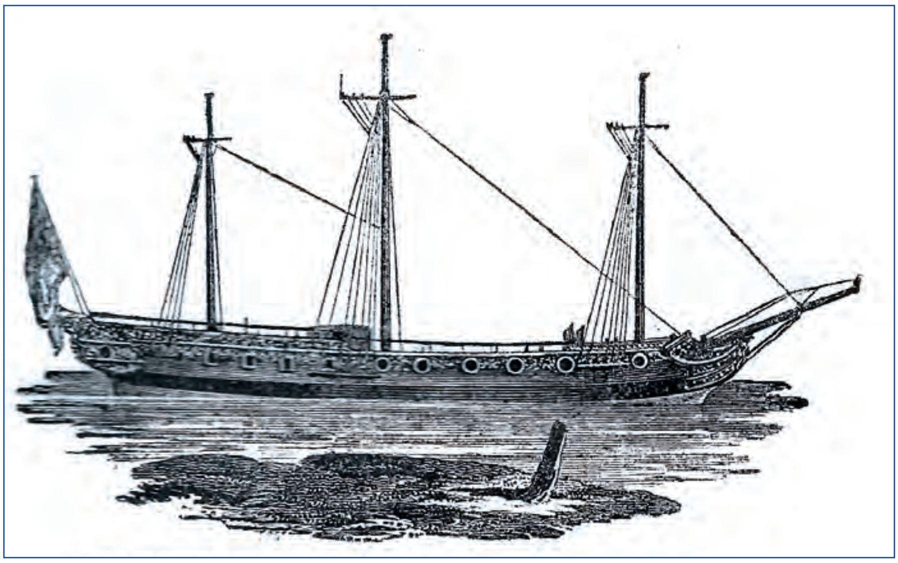
Within a few weeks of taking office he decided to make a tour of inspection of naval establishments, and particularly the two biggest, at Portsmouth and Devonport, Plymouth. During a three-week period of pretty intense activity in July and August 1827 during which, as we have seen, Canning died and Goderich took over, Clarence visited both Portsmouth and Devonport with a quick side-trip to the newest Royal dockyard, at Pembroke Dock on Milford Haven in south-west Wales. And it was during this period that he took a shine to steam propulsion in general and to the *Lightning* in particular.

William, Duke of Clarence, as Lord High Admiral. This is a print by William Ward, based on a painting by Abraham Wivell and first published in 1827, more or less at the same time as William (and the Lightning*) visited Pembroke Dock*

William's principal means of transport for the visits was to be, quite appropriately for a prince of the realm, a Royal Yacht, just as the present royal family routinely used RY *Britannia* for official visits until her decommissioning in 1997. Since 1997 there has been no official British Royal Yacht, though the Queen famously hired the cruise ship MV *Hebridean Princess* as a sort of surrogate Royal Yacht for a family holiday around the Scottish islands to mark her 80th birthday in 2006. But over the previous 330 years, the monarchy has had access to no less than 84 different yachts since the very first one, the *Mary*, was given to Charles II by the City of Amsterdam in 1660. Although there has usually been only one yacht in use at any time, on a few occasions several have been available simultaneously. At the time of William's appointment as Lord High Admiral, for example, there were no less than five official Royal Yachts, and William's choice fell on the oldest and grandest of these, the 96 feet long three-masted *Royal Sovereign*, built, like *Lightning*, in Deptford and launched in 1804.

Although we have little direct information about the routine activities of the *Lightning* and her non-*Navy List* sister steam vessels during this period, their involvement in these official visits is rather well

Illustration of the Royal Sovereign *taken from the* Naval Chronical*, Volume 13, January–June 1805. The original caption says: 'The Royal Sovereign Yacht, built at Deptford, and launched there during the summer of 1804. After which she attended the King at Weymouth, commanded by Sir Harry Burrard Neale. This Yacht is of larger dimensions than any other that had been previously built; and is a remarkaby good Sea Boat.'*



documented in a few newspaper articles and two first-hand accounts. The first account, by the artist and engraver Henry Moses, is a lavishly illustrated account of the Portsmouth visit issued some time shortly after William's accession and dedicated to Queen Adelaide who, as the Duchess of Clarence, had accompanied her husband on the dockyard visits. The second, by Sir John Barrow, the long-serving Second Secretary to the Admiralty who accompanied William in his official capacity and described all of the visits in his memoirs, was published much later.

The first visit was to Plymouth, where the *Royal Sovereign* arrived on 9 July, accompanied by HMS *Procris*. According to Barrow, the job of the *Procris* was '... for the purpose of answering signals that might be made to or from the *Royal Sovereign*', that is to act as a communications link between the Lord High Admiral's vessel and any others in the vicinity. So it was essential that she stayed in visual contact with the *Royal Sovereign* at all times. But although *Procris* was roughly the same size as the *Royal Sovereign*, she was rigged as a brig (that is, with only two masts carrying square sails), and could not keep up with the three-masted yacht. The *Procris* was one of the 115 Cherokee class brig–sloops built between 1815 and 1830, including the *Beagle* in which Darwin made his famous circumnavigation under the command of Robert Fitzroy. It was precisely because of the questionable sailing qualities of the two-masted rig that the *Beagle* was re-rigged as a three-masted barque for her first South American voyage long before Darwin joined her. Meanwhile, the brig-rigged *Procris* needed a little help, so the Lord High Admiral's little flotilla, says Barrow, included the steamer *Comet* to give her a tow.

The *Comet* was actually the very first steam vessel built by the navy, having been launched, also at Deptford, in May 1822, well over a year before the *Lightning*. At 115 feet long she was a little smaller than the 126 feet long *Lightning* and had less powerful engines built by Boulton and Watt and developing only 80 h.p. compared with *Lightning*'s 100 h.p. But despite her precedence, unlike the *Lightning*, she did not catch the eye of the Admiral and did not enter the *Navy List* until 1831, three years after the *Lightning*.

And *Comet* was not the only steamer involved in William's dockyard visits, for it seems that the flotilla also included the *Lightning* and her near identical sister vessel *Meteor*, also launched at Deptford, but a year later in 1824. Although Barrow doesn't mention her at the time, the *Lightning* was either already at Plymouth or she had also accompanied the other vessels down the Channel because, after ten days of official inspections of everything from the famous breakwater, the naval vessels, the marines and their barracks, to the offices and the book-keeping arrangements, the Lord High Admiral finally left Devonport on Saturday 21 July, again in the *Royal Sovereign*, but this time, says Barrow, accompanied by the *Lightning* and bound for Milford Haven and Pembroke Dock.

Royal coat of arms from the Royal Yacht, Royal Sovereign*, used by the Duke of Clarence for his dockyard visits in 1827. From the early 1830s, the yacht was moored in the dock to provide accommodation for successive Captain Superintendents of the Yard. When the vessel was broken up in 1849, the crest was removed to the Dockyard Chapel where it stayed until the Yard finally. closed in in 1826. It is now preserved in the National Maritime Museum in Greenwich.*

The Admiral was already quite taken by the *Lightning* because two days earlier she had had an important, if subsidiary, role in what must have been a glittering evening, a ball on the *Royal Sovereign* given by William at the request of some of the notable ladies of Devonport and Plymouth so that they could 'pay their respects to the Duchess'. To accommodate the 600 or so attendees, the *Lightning* was brought alongside the yacht to act as a sort of gangway. 'Both yacht and steamer,' wrote Barrow, 'were decorated in the most splendid manner, with the flags of all nations, intermixed with flowers and flowering shrubs; and the whole arrangement presented one of the prettiest sights I ever remember to have seen.' It must have been quite a knees-up, for Barrow reports that it cost William between £400 and £500 (equivalent to between £25K and £30K today) and that the dancing went on until four in the morning.

But despite the expense, and William's love of a good party, the Duke and Duchess left the ball soon after midnight because both of them had a busy day ahead of them. William had to complete his schedule of duties in and around the dockyard, while Adelaide – who, unlike William, did not like sailing and would avoid it if at all possible – had to set out separately on the long and arduous journey to Milford Haven.

High level endorsement of a new naval establishment

The visit of the future king and queen to Pembroke Dock was extremely important to the new dockyard. Established only 13 years earlier, in 1814, Pembroke was still establishing its reputation. By the time it closed in 1926, more than 250 naval vessels had been launched at Pembroke, including some of the largest and most innovative warships of the time and several that played important roles in the history of exploration and oceanography.

One of the most famous of all, the little bomb vessel HMS *Erebus*, the 28th vessel launched at Pembroke, had left the slips in June 1826, only thirteen months before the royal visit. Though no-one realised it at the time, of course, the *Erebus* was to have an illustrious career including participation in James Clark Ross's circumnavigation of Antarctica between 1839 and 1843 and, finally, Sir John Franklin's ill-fated search for the North-West passage in the 1850s. Amazingly, the well-preserved wreckage of the *Erebus*, and of her sister ship the *Terror*, have recently been located in the Canadian Arctic, resulting in a major exhibition at the National Maritime Museum. Another famous Pembroke-built survey vessel was the screw sloop *Alert*, launched in 1856 and selected for the British Arctic Expedition of 1875. Captain George Nares, commander of HMS *Challenger* for the first half of her historic circumnavigation

View of Pembroke Dock from West Lanion Pill (a tidal creek) from an engraving based on an 1817 sketch by Charles Norris, first published in 1820. The large building in the centre is the first of a whole series of covered slips that were eventually built in the dockyard, enabling the workforce to produce more than 250 naval vessels in the 113 years of its existence.

from 1872 to 1876, was brought home when *Challenger* reached Hong Kong in November 1874 specifically to take command of the *Alert* expedition.

But despite developing a well-deserved reputation for building excellent vessels, Pembroke was always something of a poor relation compared with other naval dockyards. Although an official Admiralty yard, it was never a naval base like Portsmouth or Plymouth. And despite being much larger than most other naval yards like Chatham and Woolwich, until the 1860s Pembroke-built vessels could not be finished in the yard because there were no facilities for installing masts and rigging in the days of sail, or engines as steam power superseded wind. Instead, once the hulls were launched from Pembroke's covered slips they had to be jury-rigged (i.e. fitted with temporary masts and sails) and taken to one of the finishing yards to put the icing on the cake, so to speak. No wonder, therefore, that the visit of the Lord High Admiral and his lady in 1827 caused such a fuss. But, as we will see, things didn't go altogether smoothly.

As Adelaide hated sailing, the last thing she wanted was to sail from Plymouth to Pembroke in the *Royal Sovereign* all the way round Land's End and across the wide mouth of the Bristol Channel, a distance of more than 200 nautical miles (n.m.) and taking at least two days even with favourable weather. On the other hand, the distance by road between Plymouth and Pembroke is even longer (more than 250 miles or 210 n.m.), well over 36 hours of bone-shaking travel on the roads of the day. So according to a report in *The Times* for 27 July, Adelaide adopted a compromise, travelling overland to Ilfracombe on the north Devon coast where she was met by the steamers *Comet* and *Meteor*. Adelaide and her entourage then boarded the *Comet* for the relatively short 60 n.m. or so crossing to Milford Haven, while the *Meteor* carried their coaches, both vessels arriving at Milford in mid-afternoon on Monday 23 July. In the meantime William had left Devonport on the Saturday, but his passage in the *Royal Sovereign* had been delayed by fog and weak winds, disastrous, of course, for a sailing vessel. The yacht eventually limped into Milford at 11 p.m. on Monday under tow by the *Lightning*, far too late to greet the Duchess, of course, but back more or less on schedule thanks largely to the presence of the three little paddle steamers.

Over the next two days, William inspected the new dockyard and Adelaide launched an 84-gun 2nd rate ship originally to have been called *Goliath* but renamed *Clarence* in honour of the visit. Finally, on 26 July they set off on their journeys to Portsmouth for the last part of the tour, Adelaide by road and William aboard the yacht, with the *Lightning*, as before, available to provide a tow if required. Next time we will pick up the story as William's flotilla rounded Land's End in foul weather and sailed up the Channel to Portsmouth where *Lightning* finally sealed her place in the Lord High Admiral's heart and, in doing so, took steam vessels into the hallowed ranks of the *Navy List*.

As an intriguing postscript, during his inspection of the new dockyard William would have been made well aware that it was acutely short of accommodation, particularly for its senior officers. Six years later, the by then 29-year-old *Royal Sovereign*, no longer considered suitable for use as a Royal Yacht, was moored at Pembroke Dock to provide accommodation for successive Captain Superintendents until she was finally broken up in 1847.

Acknowledgements

The royal coat of arms and the view of Pembroke Dock are reproduced by kind permission of Lieutenant-Commander Lawrie Phillips, author of *Pembroke Dockyard and the old navy; a bicentennial history* (see below).

Further reading

Barrow, Sir John (1847) *An autobiographical memoir of Sir John Barrow.* London.

Moses, H. (1830) *The visit of William IV when Duke of Clarence, as Lord High Admiral to Portsmouth, in the year 1827, with views of the Russian squadron at Spithead*. Ackerman and Co., London.

Pockock, T. (1991) *Sailor King. The Life of King William IV,* Sinclair-Stevenson, London, 254pp.

Phillips, L. (2014) *Pembroke Dockyard and the old navy; a bicentennial history*. The History Press, 352pp.

Rice, A.L. (1986) *British oceanographic vessels 1800–1950*, Ray Society, 193pp.

Rodger, N.A.M. (2004) *The command of the Ocean. A naval history of Britain, 1649–1815*. Allen Lane, 907pp.

Zeigler, P. (1971) *King William IV*. Readers' Union, 335pp.

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